| | |
|---|---|
| | **HOP! research project**<br>**Macro-economic impact of high oil price in Europe** |

# Deliverable 1
# High Oil Prices: a comparison of the main national and international studies

Milan, June 2007

Project co-funded by the European Commission – DG Research
6th Research Framework Programme

**HOP! Macro-economic impact of high oil price in Europe**

*Contract n.*: SSP-CT-2006-044164

*Duration*: 01.01.2007 – 30.06.2008

*European Commission – DG Research – 6th Research Framework Programme*

*Partners*: TRT - Trasporti e Territorio SRL, Milan, Italy (coordinator)

ISI - Fraunhofer Institute Systems and Innovation Research, Karlsruhe, Germany

IPTS - Institute for Prospective Technological Studies, DG-JRC, Seville, Spain

*Website*: www.hop!project.eu

*Deliverable n.*: 1

*Title*: High Oil Prices: a comparison of the main national and international studies

*Authors*: Giuseppe Casamassima TRT, Angelo Martino TRT, Burkhard Schade JRC IPTS

*Version*: 1.0

*Date*: 13 June 2007

*This document should be referenced as*:

Casamassima, Martino, Schade B. (2007): High Oil Prices: a comparison of the main national and international studies. Deliverable 1 of HOP! (Macro-economic impact of high oil price in Europe). Funded by European Commission 6th RTD Programme. Milan, Italy.

| | |
|---|---|
| *Status*: | Restricted |
| *Distribution*: | HOP partners, European Commission |
| *Availability*: | Public (only once status above is accepted) |
| *Filename*: | D1 HOP!.doc |
| *Quality control*: | Silvia Maffii TRT |

# Executive summary

The HOP! project is aimed at evaluating the direct and indirect impacts of temporary and/or permanent increase in oil price on the whole European economy, with special reference to impacts on the energy sector, transport sector and employment.

The objective of WP1 is to screen studies and scenarios within the EU and internationally. The aim is twofold: to create the basis for designing plausible scenarios and to stress the relationships between high-energy prices and consequences on the macroeconomic variables such as GDP and employment. At this regard, the outcome of this survey can be used as framework of comparison within the project.

This review analyses those studies and reports presented by international organisations and European research projects providing, either directly or indirectly, consistent projections for energy, transport and technology development in the next decades.

This review will analyse in particular some key variables that can be used in WP2 for scenario design. The main variables analysed are Global energy demand, Oil and Gas supply, oil and gas price development, fuel cost and development of new technology. A comparative analysis of such variables has been carried out and the outcome is described separately in different section of the deliverable.

The last section of the D1 addressed two separate issues; the macroeconomic impact of high oil prices and the current transport and energy policies in the UE, which could provide some useful observations for the energy scenario design to be developed in the subsequent Work package.

## I Selection of the studies and reports

The review has taken into account the ***Studies and reports of international Agencies***. They are recognised as leading sources for international policy making and the data basis for several worldwide researches. The sources of the review are as follows:

- The International Energy Agency, which published World Energy Outlook 2006 (WEO), Energy Technology Perspectives 2006;
- Energy Information Administration (EIA) , which published International Energy Outlook 2006 (IEO).

The most EU relevant ***research projects*** related to energy and transport projections as well as technology development have been considered in this review, which are the following:

- WETO-H2 - World energy, technology and climate policy outlook;

- TRENDS to 2030 and Scenarios on high oil and gas prices;
- EC European Energy and Transport. Scenarios on key drivers-trends to 2030;
- Well-to-wheels report - EC JRC + EUROCAR;
- STEPs - Transport System and Energy Supply and their potential effects;

In the review**,** the sources representing an important reference in terms of ***oil reserves and resource estimation*** have been included. British Petroleum, Oil and Gas Journal, World Oil, OPEC provide data on oil reserves. US Geological Survey provided also data on estimated recoverable oil resources.

The contribution of the ASPO (Association for the studies of Peak Oil) has also been considered; C.J. Campbell and J. H. Laherrère provide information and data concerning different oil depletion scenarios.

Different views referring also to more optimistic estimates have been taken into account in the review; a study of Cambridge Energy Research Associates (CERA) has been analysed and its data have been collected for comparison with other sources.

# II Energy Demand

The main exogenous inputs to the energy consumption relate to world population and economic growth. These last parameters are reported in WEO, IEO and WETO-H2 showing no relevant differences.

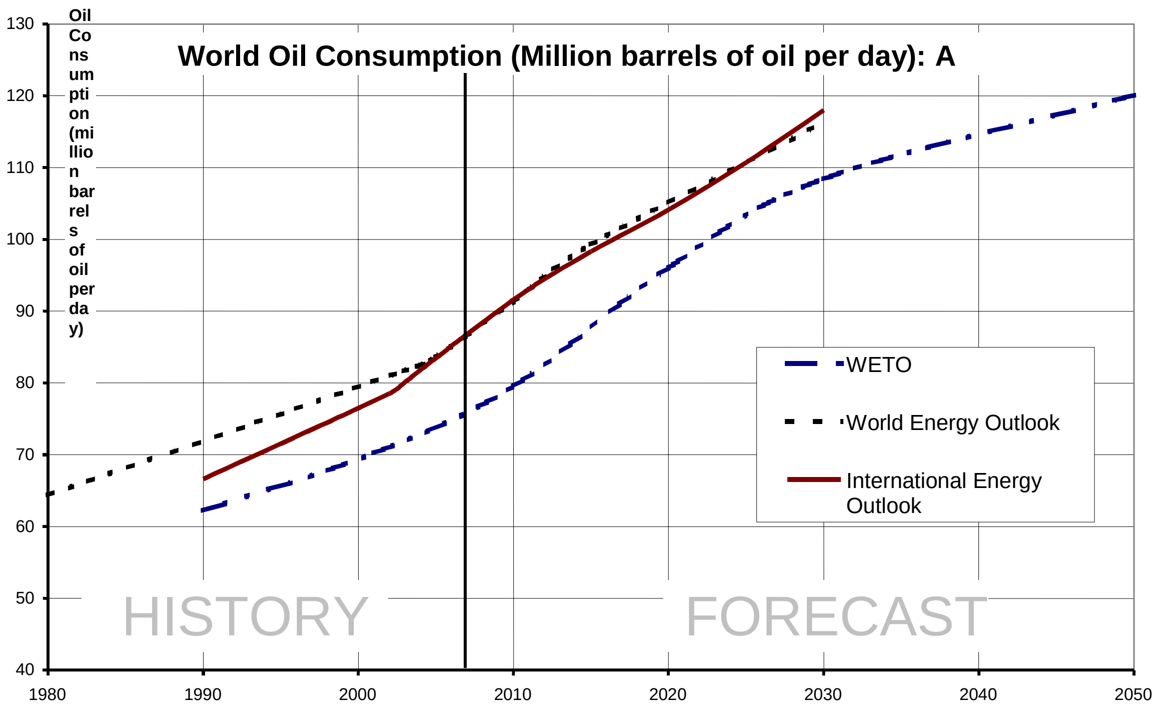
The total energy consumption in the world is expected to increase at an average annual rate that varies amongst the studies ranging from 1.7% to 2.0%. All studies agree on the hypothesis that non-OECD energy demand will expand more rapidly than OECD energy demand, especially in non-OECD Asia.

The forecasts vary also with respect to the mix of primary energy inputs. However, there is a general consensus between the publications analysed, in that the greatest demand increase in energy will be oil based fuels, notably in the transport sector. Both passenger transport and freight are expected to rise, the latter at a greater degree.

Future total world oil demand is estimated on the basis of an assumed price path and future economic growth. Worldwide oil consumption forecasts do not differ relatively between WEO and IEO where the consumption is estimated to be about 118 million barrels per day in 2030. WETO-H2 estimates provide lower figures; the world oil consumption reaches 108 mb/d in 2030 and 120 mb/d in 2050. The figure 1 shows the projections of oil consumption growth assumed by these studies.

According to the studies considered, the transport sector absorbs 63% of the increase in global oil demand in 2004-2030. In non-OECD countries, transport is the biggest contributor to oil demand growth.

Figure 1 World oil consumption projections assumed by different study




Source: TRT elaboration on mentioned studies

# III Oil and Gas Supply

There is general uncertainty in defining the oil and gas reserves and resources. The comparison of reserves and resources assessments among the various sources is complicated by differences in estimation techniques and assumptions among countries and companies. In particular, assumptions about prices and technology have a major impact on how much oil is deemed to be economically recoverable. Some studies attempted to deal with this issue, providing estimates of the recoverable rate as function of oil price (IEA).

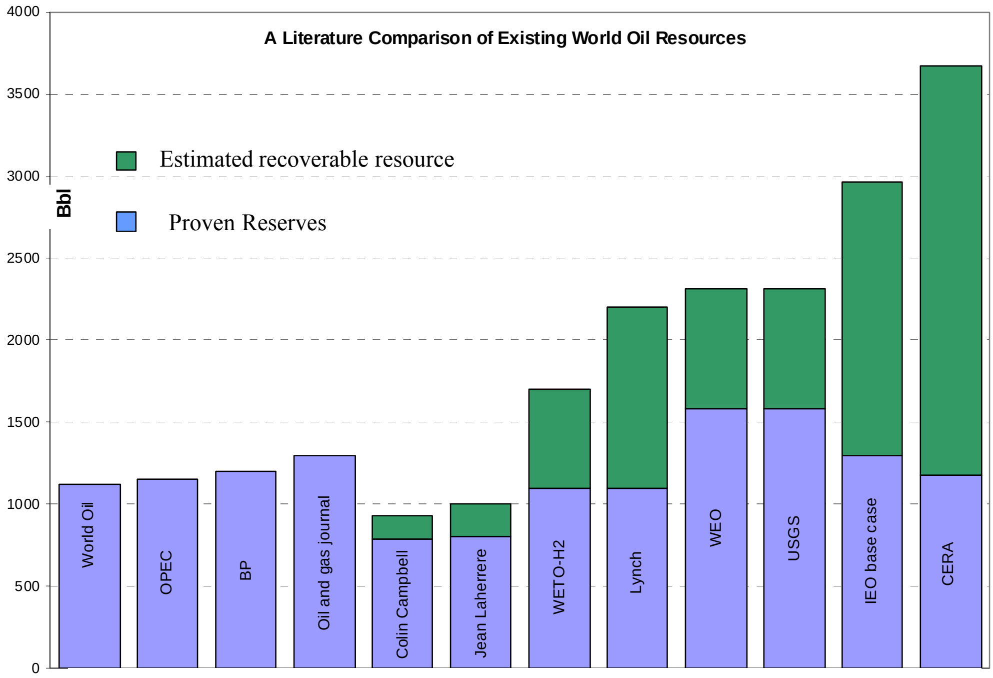
At this regard, according also to some studies (CERA) the role of non-traditional or unconventional liquid fuel in the future energy scenario could be relevant to meet the oil demand growth.

The oil proven reserves estimates reported by the studies, range from 800 Bbl to 1580 Bbl.

The amount of oil and gas discoveries that will be added to the reserve base as commercially exploitable in the next 30 years is even more uncertain as it is shown in the Figure 2. In this case, the data provided varies from 140 Bbl to 1350 Bbl.

Although all the studies differ in the figures, all agree that there is a large difference in the potential between OPEC and Non-OPEC countries. The OPEC report states that the proven OPEC reserves represent approximately 78% of the world total.

Figure 2 A literature comparison of existing world oil resources



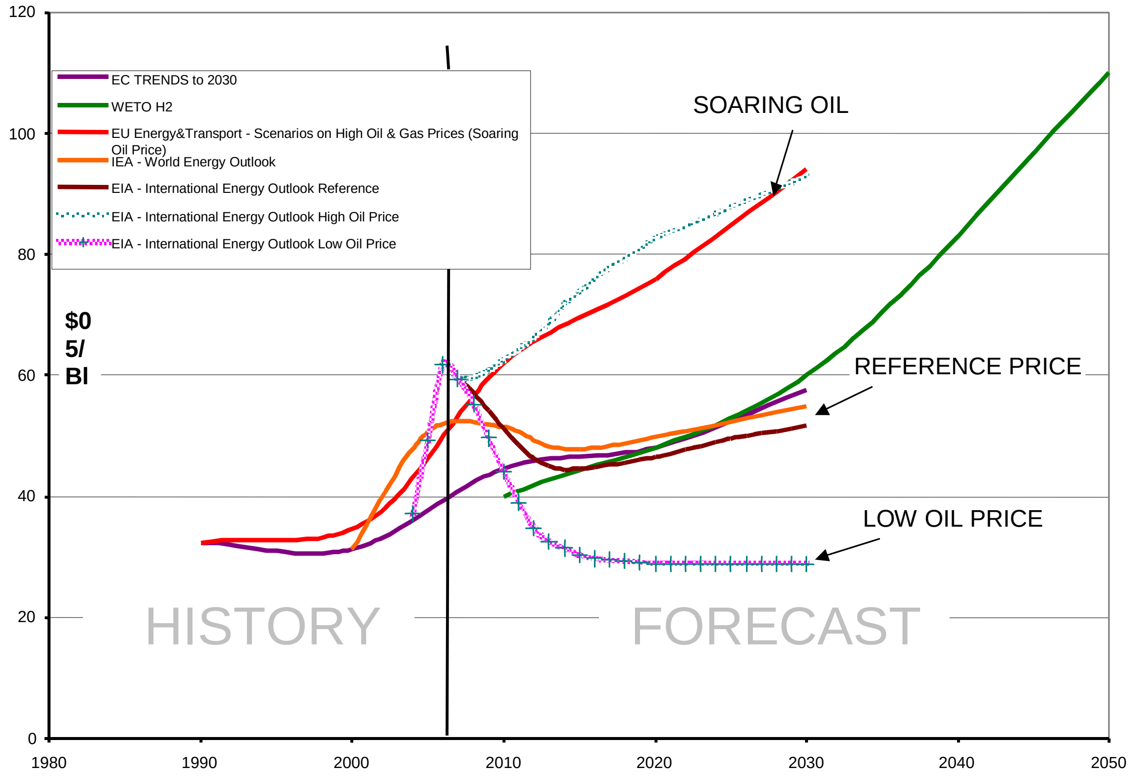

Source: TRT elaboration on mentioned studies

# IV Oil and Gas price development

In all models analysed, the fossil fuel price assumptions are based on those value needed to meet the projected demand. OPEC is assumed to be willing to meet the portion of global oil demand not met by non-OPEC producers at the given prices. The projections of oil production depend obviously on the resource availability. Nevertheless, in several studies considered, major disruptions in oil supply are not assumed being determinant for the oil price level that might be reached. The soaring oil prices scenarios refer to situation in which the world oil resources are assumed to be smaller than those estimated in the reference case. The oil prices projections assumed in the studies range from $52 per barrel in 2030 in reference scenarios to $99/Bl in 2030 when soaring oil prices scenario is assumed (in real year-2005)(Fig. 3).

Most of the studies considered derived the Natural Gas demand from a gas price assumed that is linked to the oil import price. The possibility of gas price decoupled from oil prices has been investigated; In this case, relevant changes in the fuel mix as well as in terms of improving energy intensity can be expected.

Figure 3 Estimated world oil prices assumed by different studies




Source: TRT elaboration on mentioned studies

# V Transport technology and fuels

Most of the energy used for transport purposes today is in the form of oil products; 95% of the energy demand of total transport is fulfilled by petroleum products. The remaining 5% is provided by natural gas (for road transport and pipelines), electricity and coal (for rail transport) and biomass (in the form of liquid fuels) (IEA, 2006).

Analysing fuel consumption, it can be stated that petroleum based fuels such as gasoline, diesel and jet fuels dominate the market, a situation which has remained unchanged over the past years. However, three notable changes of the energy fuel mix can be observed; the shift to diesel vehicles in Europe, the electrification of railways in many OECD countries and the growth of bioethanol in Brazil.

The increase in oil and gas prices would encourage the development of new technology based on renewable sources. Transport sector uses of hydrogen and biofuels might play an important role in the near future. In Europe conventional biodiesel production is estimated at just over $0.60 per litre of diesel equivalent, which means that only oil crude prices of over $70 would make this option competitive against conventional gasoline and diesel (IEA 2006). The availability of space for producing large amount of biofuels and the environmental impact of life-cycle production should be taken into account.

Hydrogen/Fuel Cells (HFC) technologies are expected to enter the transport market in the long term (2030) but will still face major obstacles. However, according to studies considered (Hansen, 2006), HFC solutions will be competitive to conventional Light duty vehicles (LDV) solutions even at the current (2006) oil price if the vehicle costs are equal and the non-energy costs of hydrogen are €10 per GJ.

# VI Studies on Macroeconomic impact of high oil prices

The quantitative impact of higher oil prices on the economy of a certain country, expressed as GDP or employment variation, has been derived mainly by econometric studies performed by International Monetary Fund, Energy modelling Forum, International Energy Agency and Energy information administration. Synthetic result of system dynamic models used in STEPS has also been provided in the last part of this section.

From the macroeconometric studies analysed, a provisional observation can be derived; a sustained $10 per barrel increase in international crude oil prices would cut average real GDP by -0.3% -0.5% as a whole compared with the baseline, with different impact on OECD and Non-OECD countries or whether oil-exporting or oil importing countries are considered. Most of these effects would be felt within one to two years, with GDP returning broadly to its baseline growth rate thereafter.

According to the system dynamic model STEPs the effect on economy development as well as on transport demand is small. GDP and employment grow sharply over the modelled period and their level at the 2030 horizon is slightly lower when compared to a slower pace of oil price development.

# LIST OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# 1 Introduction

## 1.1 The HOP! project

The HOP! project is aimed at evaluating the direct and indirect impacts of temporary and/or permanent increase in oil price on the whole European economy, with special reference to impacts on energy sector, transport sector and employment.

The project is co-funded by the European Commission DG Research and is undertaken by three partners, with TRT Trasporti e Territorio taking the lead and collaborating with Fraunhofer Institute Systems and Innovation research (ISI) and the Institute for Prospective Technological Studies of the European Commission DG JRC (IPTS).

The HOP! approach will develop along three activity lines:

- *Modelling:* the quantification of the impacts will be performed by coupling two European strategic models, the ASTRA model (designed for the long term assessment of transport policies and investments) focused on transport and macroeconomics and the POLES model (designed for simulating the interaction of energy supply and demand) focused on energy.
- *Assessment:* the scenarios to be compared in HOP! modelling will be carefully designed to allow for identifying a well defined set of impacts; a good deal of competent assessment will be necessary for analysing quantitative indicators produced by running ASTRA and POLES as well as for complementing quantitative evaluations with qualitative ones.
- *Scientific consensus:* the HOP! project will organise two scientific workshops in Brussels: the first one will be devoted to the discussion of the high oil price scenarios and the second one to the discussion of the quantified impacts.

The HOP! project will deliver quantitative results about the energy sector, the transport sector and the economy that could be used in EU policy-making. In terms of final modelling output, i.e. the scenarios results, the attempt will be of producing a set of meaningful indicators presented in a clear and concise way so that main responses can be readily captured and compared.

## 1.2 The objective of WP1

The objective of this work package is to screen studies and scenarios within the EU and outside. The aim is twofold: to create the basis for designing plausible scenarios and to stress the relationships between high energy prices and consequences on the macroeconomic variables such as GDP and employment. At this regard, the outcome of this survey can be used as framework of comparison within the project.

The HOP! scenarios will test the impact of different levels and characteristics of high oil prices (i.e. permanent or temporary) and will be selected in the subsequent activities of the project (WP2) on the basis of different combinations of future trends for the key scenario variables. In principle, these key variables might include:

(a) Fossil fuel reserves;

(b) Cost of alternative energy and transport technologies;

The analysis of fossil fuel reserves (item a) is definitely relevant as this influences the rate of oil extraction in future years and consequently the capability of the suppliers to match the constantly growing demand. The same analysis also includes the progress of technical capability to exploit fossil reserves at competitive costs.

Information about the development of the costs of alternative energy and transport technologies is needed to understand which energy sources might act – in the long term – as oil substitute, taking into consideration their cost and their verifiable availability.

## 1.3 The review of studies, models and policy documents

Model based “scenarios” are increasingly used within the *international energy community* to generate projections of future energy consumption consistently related to factors that influence energy consumption in various sectors and regions, such as rates and patterns in economic growth, developments of population, available income or motorisation levels. Such links are based on both evidence concerning past trends and assumptions concerning variations in energy efficiency of different sectors.

Medium term projections (2020-2030) for energy supply and demand in various sectors and regions across the globe are regularly produced by updating ‘official’ statistics, analyses and forecasts for economic development by the International Energy Institutions.

The survey of relevant studies at national and at international level will include different sources; international agencies and institutions, industry and financial institutions and European RTD projects.

## 1.4 The report structure

The report is divided into 9 sections, followed by references, a glossary, and a list of abbreviations.

The **first section** delivers an introduction to the HOP! project and framework, and describes the outline of the report.

**Section 2** summarises current international and European research, published in the last five years, relating to energy and transport policies and demand forecasts. This section also explores current technological developments in these sectors, and their forecast usage.

In **Section 3**, the current reports regarding energy demand are considered on a geographical basis, specifically as a function of population increase, GDP, and type of economy. Various economic scenarios will be explored in greater detail, with the methodology of these studies dissected and evaluated for adoption in the HOP! model. The study will focus primarily on oil and gas demand.

**Section 4** follows by analysing the supply forecasts of oil and gas. These forecasts are based on peakist and optimist postulations. Additionally, this section considers the projections remaining resources and levels of production over the next 25 years, categorised by report and forecast model.

**Section 5** discusses the mechanisms involved and methods adopted to generate world market oil prices.

**Section 6** concentrates on the potential of emerging fuels and technologies in the transport sector, such as biofuels and hydrogen. Each option is discussed in terms of recoverability and market potential.

**Section 7** discusses the economic consequences of high oil prices or oil shocks.

**Section 8** discusses the current energy and transport policies in the EU, and their possible significance for HOP! scenarios. The section also lists all relevant future developments such as new policy introductions and appraisals.

Lastly, **section 9** summarises the key findings of the analysed forecasts and attempts to give inputs to the WP2.

# 2 Selection of studies and reports

## 2.1 Introduction

This review analyses those studies and reports presented by international organisations and European research projects providing, either directly or indirectly, consistent projections for energy, transport and technology development in the next decades. A short description of each author and the characteristic of the documents are provided in this section. Comparative analysis of the data is provided in the next chapters.

Particular emphasis is placed on the oil and gas resource estimates and on the oil depletion scenarios. The data on oil resources, such as reserve estimation and oil production, are crucial to define the energy scenarios and the oil prices development, which is the key information for the design of the HOP! scenarios. Main data sources in this field are oil companies, oil industry journals and scientific organisations.

## 2.2 Studies and reports of international agencies

Studies of international agencies are recognised as leading sources for international policy making and the data basis for several worldwide researches.

### 2.2.1 International Energy Agency (IEA)

The International Energy Agency (IEA) is an autonomous agency linked with the Organisation for Economic Co-operation and Development (OECD). IEA is considered as the world's leading source of energy statistics, assembling annual, quarterly and monthly reports on oil, gas, coal and overall energy supply, consumption, prices and taxes.

The *World Energy Outlook* is the report that IEA releases annually. Issues covered include: oil exploration and production developments; supply, demand, price and refining trends; and international trade in crude and products. Thanks to the intergovernmental role of the IEA, the WEO is in an exclusive position to provide objective energy analysis and energy projections covering the entire world. The WEO has influence on energy policies in IEA member countries and has received widespread international recognition.

The WEO uses two main scenarios. The Reference Scenario takes into account policy measures that were adopted in mid-2002 including recent efforts relating to the Kyoto Protocol and targets for renewables and suggests that

- energy use continues to rise rapidly, fossil fuels will dominate the energy mix, and the energy consumption of developing countries approaches that of the OECD;

- $CO_2$ emissions are expected to grow slightly faster than energy consumption despite the measures taken to date.

The Alternative Policy Scenario assesses the impact of a range of new energy and environmental policies that OECD countries are considering and faster deployment of new technologies; it demonstrates a strong impact of new policies to curb energy demand growth and the energy mix; the latter would also have positive consequences for import dependence of the OECD.

In the year 2006, IEA published the *Energy Technology Perspectives – Scenarios & Strategies to 2050*, which was a response to the Group of Eight (G8) leaders at their Gleneagles Summit in July 2005; the document presents the status and the prospects for key energy technologies and assesses their potential by 2050.

The IEA's World Energy Model (WEM) is a large-scale mathematical construct designed to replicate the energy market's function. It provides detailed sector-by-sector and region-by-region projections for both the reference and alternative scenarios. The model is made up of five modules: final energy demand; power generation; refinery and other transformation; fossil-fuel supply and $CO_2$ emissions. The WEM has been revised in 2004, where new regional demand models and new supply models for oil and coal production and trade have been included; the model has been further extended for the *World Energy Outlook (WEO) 2006*.

### 2.2.2 Energy Information Administration (EIA)

The Energy Information Administration (EIA) is the independent statistical and analytical agency within the U.S. Department of Energy. EIA provides energy information for use of Congress, the Administration and the public and, however, does not take positions on policy issues. The *International Energy Outlook* is the report released yearly by the EIA and presents international energy projections through 2030, including outlooks for major energy fuels and associated carbon dioxide emissions. The EIA's NEMS model is a General equilibrium energy-economic model of U.S. energy markets with energy-related emissions. Emissions modelling include energy system-wide carbon dioxide and methane emissions. NEMS represents energy supply, demand, and conversion sectors of domestic energy markets, plus international and macroeconomic modules[1].

The *International Energy Outlook* 2006 has three scenarios; a baseline scenario, a high economic growth scenario and a low economic growth scenario. The report also makes predictions of the total carbon dioxide generation for each scenario.

1 http://www.epa.gov/cleanenergy/pdf/model_sum_nems_100202.pdf

Table 2.1 Relevant studies and reports of international agencies

| | International Energy Agency (IEA) | | Energy Information Administration (EIA) |
|---|---|---|---|
| **Report** | World Energy Outlook (WEO) 2006 | Energy Technology Perspectives | International Energy Outlook (IEO) 2006 |
| **Main theme** | Energy | Technology | Energy |
| **Projections** | Medium-term and long term (2030) | Medium-term and long term (2050) | Medium-term and long term (2030) |
| **Model** | World Energy model | ETP Energy Technology Perspective models | International Energy Module of NEMS |
| **Scenarios** | Reference case[2]<br>World alternative policy scenarios | Reference case<br>World alternative policy scenarios | Reference case[3]<br>High and low economic growth<br>High and low oil cases |

## 2.3 EC studies and research projects

Several European research projects have analysed the energy system and its future trend responding to the needs of the EU policy-makers to know more about potential impact of many policy options. The most EU relevant research projects related to energy and transport projections as well as technology development have been considered in this review.

Table 2.2 summarises these studies and research projects, providing information about the model, the alternative scenario tested and the time horizon. POLES, PRIMES and ASTRA are the models used in these studies.

2 The Reference projection describes a continuation of existing economic and technological trends, including short-term constraints on the development of oil and gas production and moderate climate policies for which it is assumed that Europe keeps the lead.

3 The Reference scenario assumes that no new government policies are introduced during the projection period; alternative policy scenario analyses the impact of additional measure to address energy-security and climate change concerns.

Table 2.2 EC studies and research projects

| | EC Scenarios on high oil and gas prices | WETO-H2 | EC European Energy and Transport. Scenarios on key drivers-trends to 2030 | STEPS | Well-to-wheels report | TRIAS |
|---|---|---|---|---|---|---|
| **Author** | **EC DG TREN** | **EC DG TREN** | **EC DG TREN** | **EC DG RTD research project** | **EC JRC + EUROCAR** | **EC DG RTD research project** |
| **Main theme** | Energy and Transport | Energy and technology | Energy and transport | Energy and transport | Technology Development | Energy and technology |
| **Time horizon** | 2030 | 2050 | 2050 | 2030 | Long term | 2030 |
| **Model** | POLES | POLES | PRIMES | ASTRA, POLES | | ASTRA, POLES |
| **Scenarios** | - Base<br>- High oil and gas prices decoupled scenario | - Base<br>- Low oil and gas resources<br>- High gas reserves<br>- Techn. Development<br>- Carbon constraint<br>- Hydrogen scenario | - Base<br>- High oil and gas<br>- High and low economic growth<br>- Alternative policy scenario | - Base<br>- Technology<br>- Demand<br>- High oil variant | | - Technology development<br>- Innovation Funding policies |

### 2.3.1 WETO-H2

The Commission published its “World energy, technology and climate policy outlook” (WETO) in 2003. It compares two different scenarios: a “business-as-usual” and a Carbon Abatement Scenario, looking at the impact that climate change policies can have. This assessment aims to help define priorities for the policies that can be put in place to improve the performance towards reducing $CO_2$ emissions. The Energy and Transport Update, released in 2005, makes a similar analysis with a “business-as-usual” simulation and energy reduction simulation. Main findings of the Reference Scenario are:

- world energy demand is expected to grow by about 1.9 per cent per year from 2000 to 2030;
- industrialised countries will experience a plateau in their energy demand, but demand in developing countries will increase rapidly; by 2030, the majority of the world energy demand is expected to come from developing countries, from 40 per cent today;
- fossil fuels are expected to dominate the world energy system, with almost 90 per cent of total energy supply in 2030; oil is expected to remain the main source of energy (34 per cent), then followed by coal (28 per cent) and lastly natural gas (25 per cent);
- in the EU, gas will be the largest energy source after oil, while nuclear and renewable energies will represent less than 20 per cent of EU energy supply.

The Alternative Scenario findings offer a slightly different view:

- 11 per cent decrease in the expected world energy consumption compared to the Reference Scenario; the average growth in demand would thus be 1.3 per cent per year, as opposed to 1.9 per cent;
- impact on carbon intensity, i.e. the global energy mix: a carbon value would primarily affect fuels with the greatest carbon content, namely coal (-42 per cent) and oil (-8 per cent), while gas would remain virtually unchanged. Worldwide, this market share would be taken up by nuclear energy (+36 per cent) and renewable energies (+35 per cent);
- within the renewables sector, wind, solar and small hydro are expected to increase twenty times;
- global $CO_2$ emissions would be reduced by 21 per cent compared to the Reference Scenario; however, they would still be higher in 2030 than they were in 1990;
- Europe's emissions level would be nearly 15 per cent lower than the 1990 level, and 26 per cent lower than in the Reference Scenario by 2030;
- the EU's changes in the energy mix reflect the world pattern, but both coal (-61 per cent) and oil consumption (-13 per cent) are considerably lower;

In the EU, this decrease is compensated by nuclear (+35 per cent) and renewable energy (+56 per cent).

### 2.3.2 European energy and transport – Scenarios on key drivers

“Scenarios on key drivers” considers alternative energy futures as distinct from the baseline development, which shows the effects of current trends and policies. The key drivers concern two distinct areas: i) various framework conditions for energy and transport policies, such as higher world energy prices, higher or lower economic growth; ii) policy approaches on energy efficiency, renewables, nuclear energy, modal split in transport and climate change. The analysis covers the European Union of 25 Member States and extends to the year 2030. According to the Baseline Scenario:

- energy demand continues to grow in the EU-25, but at a considerably lower pace than GDP;
- renewable energy forms exhibit the highest growth among all energy forms under Baseline assumptions (+1.9% pa in 2000-2030; more than three times higher than the corresponding growth in overall primary energy needs);
- transport sector accounts in 2030 for 32.2% of energy requirements and 49.3% of CO2 emissions in the demand side (from 30.9% and 42.6% respectively in 2000);
- fossil fuels will continue playing a predominant role in satisfying energy needs in the EU-25 over the projection period, exhibiting however reverse trends in the horizon to 2015 and in 2015 to 2030.

In the high oil and gas prices case world oil and gas prices are 20% and 33% higher respectively than in the Baseline in 2030; demand for liquid fuels remains unchanged (-1.5% from Baseline levels in 2030) as the oil price increase does not lead to changes in market share of transport, the main industry of oil consumption in the EU. Eventually, the share of renewables in primary energy needs reaches 10.3% in 2030

### 2.3.3 EU Energy and Transport – Trends to 2030

The Energy and Transport –Trends to 2030 represents the reference case on which the study reported above was based. The version analysed here refers to the updated version, released in 2005. Its outlooks produce forecasts for the future global energy condition, especially in terms of energy demand, energy mix and security of supply. The main outcomes of the its forecasts are:

- transport energy demand in 2030 is projected to be 21% higher than in 2000. However, this growth is not consistent, and there is a gradual reduction of 0.1% between 2020 and 2030;
- the market share of biofuels in 2010 rises strongly to almost 4% of gasoline and diesel oil consumption in the transport sector;

- in 2030, $CO_2$ emissions in the transport sector are expected to be 12.7% higher than in 2000. However, growth of Transport related $CO_2$ emissions curtails towards 2020 and eventually reverses.

### 2.3.4 The POLES model

The POLES model is a simulation model for the development of long-term (2030) energy supply and demand scenarios for the different regions of the world. The model is developed and maintained by DG JRC/IPTS. The development of the model and of the corresponding scenario studies intends to fulfil five main objectives:

- detailed world energy system scenarios;
- strategic areas for emission control policies;
- analysis of RTD strategies;
- assessment of Marginal Abatement Costs for $CO_2$ emissions and simulation of emission trading systems;
- impacts on international markets and price feedback.

The importance given to price mechanisms, either in the national modules or in the international modules, in fact allows for the study of different interconnected issues such as the consequences of emission control strategies on the price of internationally-traded fuels and on the producers revenues or on the corresponding negative price-feedback's in the consumer countries. It can be noted at last that the detailed treatment of price-effects in each part of the model also allows for the simulation of internalisation strategies through prices and the use of eco-taxes.

The model structure corresponds to a hierarchical system of interconnected modules and articulates three level of analysis: i) international energy markets; ii) regional energy balances; iii) national energy demand, new technologies, electricity production, primary energy production systems and $CO_2$ sectoral emissions.

The dynamics of the model corresponds to a recursive simulation process, common to most applied models of the international energy markets, in which energy demand and supply in each national / regional module respond with different lag structures to international prices variations in the preceding periods. In each module, behavioural equations take into account the combination of price effects and of techno-economic constraints, time lags or trends.

### 2.3.5 The PRIMES model

PRIMES is a modelling system that simulates a market equilibrium solution for energy supply and demand in the European Union member states. The model determines the equilibrium by finding the prices of each energy form such that the quantity producers find best to supply match the quantity consumers wish to use. The equilibrium is static (within each time period) but repeated in a time-forward path, under dynamic relationships.

The model is behavioural but also represent in an explicit and detailed way the available energy demand and supply technologies and pollution abatement technologies. The system reflects considerations about market economics, industry structure, energy/environmental policies and regulation. These are conceived so as to influence market behaviour of energy system agents. The modular structure of PRIMES reflects a distribution of decision making among agents that decide individually about their supply, demand, combined supply and demand, and prices. Then the market integrating part of PRIMES simulates market clearing.

PRIMES is a general purpose model. It is conceived for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies. A fundamental assumption is that producers and consumers both respond to changes in price. The factors determining the demand for and the supply of each fuel are analysed and represented, so they form the demand and/or supply behaviour of the agents. Through an iterative process, the model determines the economic equilibrium for each fuel market. Price-driven equilibrium is considered in all energy and environment markets, including Europe-wide clearing of oil and gas markets, as well as Europe-wide networks, such as the Europe-wide power grid and natural gas network.

Although behavioural and price driven, PRIMES simulates in detail the technology choice in energy demand and energy production. The model explicitly considers the existing stock of equipment, its normal decommissioning and the possibility for premature replacement. At any given point in time, the consumers or producer selects the technology of the energy equipment on an economic basis and can be influenced by policy (taxes, subsidies, regulation) market conditions (tariffs etc.) and technology changes (including endogenous learning and progressive maturity on new technologies)

Due to the heterogeneity of the energy market no single methodology can adequately describe all demand, supply and conversion processes. On the other hand, the economic structure of the energy system itself facilitates its representation through largely separable individual units, each performing a number of individual functions.

### 2.3.6 The ASTRA model

ASTRA has originally been developed to analyse the long-term consequences of European transport policies. Further developments made it an integrated impact assessment tool not only for transport but also for analysis of technology, employment and energy policy.

The model is based on the System Dynamics methodology and follows system analytic concepts, which assume that the implemented real systems can be conceived as a number of feedback loops that are interacting with each other. These feedback loops are implemented in ASTRA and the model is calibrated for key variables for the period 1990 until 2003.

The spatial coverage extends over the EU25 countries plus Bulgaria, Norway, Romania and Switzerland. Each country is further disaggregated into at maximum four functional zones classified by their settlement characteristics.

ASTRA is composed out of eight modules that are all integrated within one model:

- population module (POP): changes in population levels and population structures belong to the most important policy drivers in the next decades, which is reflected by integrating a one-year-age cohort based population model into ASTRA;
- macroeconomics module (MAC): the MAC balances supply and demand of the 29 national economies calculated from a Keynesian style demand side and a neoclassic style supply side with endogenous technological progress. Sectoral interactions are considered with an input-output model based on 25 sectors from which employment impacts are derived. A government model completes the economic agents of ASTRA. The MAC is connected with most other modules via macro-micro- and micro-macro-bridges;
- foreign trade module (FOT): models bilateral-sectoral trade flows between the EU29 countries and from EU29 to 10 rest-of-the-world regions;
- regional economics module (REM): provides the split of the macroeconomic drivers onto functional zones and calculates the transport demand of the zones;
- transport module (TRA): calculates the modal-split taking into account transport cost, energy prices and capacity restrictions;
- vehicle fleet module (VFT): models the vehicle fleet composition per country in terms of technologies, age and emission standards for cars, buses, light and heavy trucks depending on economic influences;
- environment module (ENV): calculates fuel consumption, accidents and emissions for all transport modes based on the vehicle-kilometres travelled coming from TRA;
- welfare measurement module (WEM): provides intensity indicators e.g. transport CO2 / GDP and predefined assessment schemes e.g. CBA to derive the welfare implications of the analysed policies and scenarios compared to a reference scenario.

## 2.4 Studies and reports on oil and gas resources

This section is devoted to sources representing an important reference in terms of oil reserve and resource estimation as well as oil industry activities in general. Documents are classified according to the type of source; oil companies, oil industry journals, non-governmental scientific organisations and independent energy consultants. A specific part of the text is dedicated to modelling studies on oil production capacity that have taken part in the peak oil debate lately.

A preliminary consideration is about oil and gas data, which are not as accurate and reliable as needed. The information on cumulative production is quite trustworthy, as the companies meter the oil as it flows from the wells. However, getting good estimates of oil and/or gas reserves is much more complicated, which is why the resource assessment is made in terms of probability. Furthermore, oil companies and countries are tempted to exaggerate the reserve reported as this can raise the value of oil companies stock[4], and in the case of the OPEC countries, the higher their reserves, the more oil they are permitted to export.

Since there is no consensus on how to assess reserves and official definitions seem to be ignored by the industry[5], the possibility of comparing different outcomes amongst several sources is difficult. It must be noted that the possibility of including non-conventional oil in the resources estimation can distort a sound appraisal of their size and their potential use, because extraction costs for non-conventional oil are much higher than for conventional.

### 2.4.1 British Petroleum and other oil industry Journals

BP is one of the world's largest energy companies, providing fuel for transportation, petrochemical products and energy for heat and light. BP publishes data series for proved oil and gas reserves, world oil production as well as oil consumption. Data series is compiled using a combination of primary official sources and third-party data. Oil reserves include condensate and natural gas liquids. Canadian oil sands 'under active development' have also been included in proved oil reserves in the most recent documents.

Each year, the two journals *Oil and gas journal* and *World oil* query oil firms and governments around the world; production and reserve numbers are then published without any verification of their validity. The two Journals are often mentioned in this report as being the main reference for most of the studies that were considered.

### 2.4.2 OPEC

The Organisation of Petroleum Exporting Countries (OPEC)[6] was founded in Baghdad, Iraq, in September 1960, to unify and coordinate members' petroleum policies. OPEC members' national oil ministers meet regularly to discuss prices and, since 1982, to set crude oil production quotas. OPEC owns about 70% of proven oil reserves and its countries are highly dependent on oil revenues. The organisation collects price data on a "basket" of crude oils, and uses average prices for these oil streams to develop an OPEC reference price to monitor world oil market.

---

4 In 2004 Shell company was involved in a scandal when it admitted to have overestimated the oil reserves by 20%.

5 UN Framework Classification (2004, 2007)

6 The OPEC members are Algeria, Indonesia, I.R. of IRAN, Iraq, Kuwait, Libia, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

OPEC produces annual statistic bulletin, which includes data about oil and gas production, exploration and reserves (not only for its members), oil consumption and prices evolution.

In the OPEC Long Term Strategy report 2006 it is stated "*In meeting the future growth of world oil demand, oil resources are large and sufficient, and oil supply will not peak within the considered time frame (2020). Moreover the size of the global upstream investment challenge will not be markedly different from the past, despite the growing volume, as capital will be increasingly used more efficiently in lower cost OPEC Countries*[7]".

### 2.4.3 Scientific organisations

U.S. Geological Survey (USGS) collects, monitors, analyses and provides scientific understanding about natural resource conditions. The International Energy Agency, the Energy Information Administration and the European project using POLES model, used the estimations made by USGS for the Ultimate Recoverable Resources.

### 2.4.4 Modelling studies on oil production capacity

Petroleum is produced from reserves discovered some years ago and current rates of production (which are forecasted to rise) are exceeding the rate of new reserve discovered. If this does not change, a supply shortage is envisaged to occur within this century. When it will precisely occur is highly contested. The studies presented below attempt to depict the oil depletion scenarios using different modelling tools and assumptions. The results of these studies will be outlined in the section of oil and gas reserve and resources, subsequently in chapter 3.

It should be recalled that the oil production models listed here below do not normally address short term fluctuations that reflect, for example, enhanced geopolitical instabilities (with the exception of the WOCAP model). This issue has been used by the Lynch study (Lynch, 2003) to undermine the credibility of this type of models, as explained below.

- C.J. Campbell, J.H. Laherrère (Campbell, Laherrère, 1998) They emphasized the limited reliability of "technical" evaluation of reserves because of their overestimation for financial reasons, mentioning - as an example - the Middle East oil reserves growth during 1986-90 without any new discover. They applied a refinement on the technique used by Hubbert[8] and provide independently different estimation about oil depletion scenarios.

- The Bakhtiari WOCAP model (Bakhtiari, 2004) is a simple mathematical model of the iterative type, with the year as its basic computing step. At its very foundation are conventional oil's global "Ultimate Recoverable Reserves" (URR) of 1,900 billion barrels developed by Campbell. Other relevant inputs are taken from either the BP PLC databases

[7] OPEC Long-Term strategy April 2006

[8] In 1956 Hubbert observed that in any large region, unrestrained extraction of a finite resource rises along a bell-shaped curve that peaks when about half the resource is gone (M.K. Hubbert, 1958).

or the author's personal sources. Bakhtiari adds in his model further factors influencing oil producing capacities: adequate upstream maintenance of existing installation; timely projects of Enhanced Oil Recovery (EOR); new oil field discoveries; annual withdrawal from known producing fields; political intangibles; geopolitical intangibles.

- The purpose of Guseo R. World Oil Depletion Models (Guseo, Della Valle 2006) is to forecast through a Generalized Bass Model (GBM) based on the "diffusion Method" world crude oil peak and global oil evolution of crude oil production in the following years, evaluating the relative significance of price shocks compared with technological or political upheavals. The use of production data, combined with exogenous interventions, avoids the problem of unreliable reserves estimations and represents an innovative way to face this aspect. It should be noticed that two very different models WOCAP and GBM had arrived at the same conclusion in forecasting the "peak"

- The nature of forecasting errors in this area is discussed by Lynch (Lynch, 2003) with reference to geophysical models and, in particular, to the Hubbert's model. The pure Hubbert's model has no room for oil economics, since the basic differential equation is the classical logistic. Lynch supposes that the origin of the problem relies on the strong assumption of a static URR. The impact of technology in expanding resources is sometimes reasonable, but rare systematic interventions may affect normal dynamics[9] and these radical changes are not recognized by a simple Hubbert model.

- In contrast to the discussed theory that the world oil production will reach soon a peak and go into a sharp decline, a new analysis of the subject by Cambridge Energy Research Associates (CERA) finds that the remaining global oil resource base is actually 3.47 trillion barrels and that the "peak oil" argument is based on faulty analysis (CERA, 2006). According to the recent report, the global production will eventually follow an "undulating plateau" for one or more decades before declining slowly. During the last decades of such a plateau period, demand growth will not be largely met by growth in available commercially exploitable oil supplies, but non traditional or unconventional liquids fuels will need to feel the gap.

[9] In order to make an example, the forced production of Prudhoe Bay in Alaska was a positive shock, while, on the contrary, the negative effect of accidents in pipelines (Piper Alpha disaster) in the North Sea depressed regular production. These accidents led to a restructuring of UK offshore safety legislation followed by major changes to the Petroleum Reven Tax. See also www.energyseer.com/NewPessimism.pdf.

Table 2.3 Classification of studies and reports

| | **Demographic and macroeconomic assumptions** | | **Global and energy projections** | | **Oil and gas market** | | **Technology development** | | **Transport** | | **Macroeconomic Impact of high oil prices** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Population | GDP | Energy Demand | Prices | Demand | Reserves & resource estimation | Production | H2 | Biofuels | *Other renewables* | Demand | |
| **Energy** | | | | | | | | | | | | |
| IEA - World Energy Outlook | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | | ▲ | | ▲ | ▲ |
| EIA - International Energy Outlook | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | | ▲ | | ▲ | |
| WETO-H2 | ▲ | ▲ | ▲ | ▲ | ▲ | | ▲ | | ▲ | | | |
| EC - trends to 2030 | | | ▲ | ▲ | | ▲ | | | | | | |
| **Resource availability** | | | | | | | | | | | | |
| Oil and gas journal, 2006 **(O&GJ)** | | | | | | ▲ | | | | | | |
| British Petroleum, 2005 | | | | | | ▲ | ▲ | | | | | |
| CERA 2006 | | | | | | ▲ | | | | | | |
| US Geological Survey, 2000 | | | | | | ▲ | ▲ | | | | | |
| C.J. Campbell, J.H. Laherrère, 2004 | | | | | | ▲ | | | | | | |
| M.C. Lynch. 2003 | | | | | | ▲ | | | | | | |
| Guseo R. 2006 | | | | | | ▲ | | | | | | |
| Bakhtiari A.M.S., 2004 | | | | | | ▲ | ▲ | | | | | |
| OPEC Annual Report | | | | | | ▲ | ▲ | | | | | |
| **Transport** | | | | | | | | | | | | |
| EU Energy and Transport Trends to 2030 | | | ▲ | | ▲ | | | | | | ▲ | |
| STEPS | | | | | | | | | | | ▲ | ▲ |
| **Technology** | | | | | | | | | | | | |
| IEA-Energy technology perspectives 2006 | | | | | | | | ▲ | ▲ | ▲ | | |
| TRIAS | | | | | | | | ▲ | ▲ | | | |
| Well-to-wheels Report | | | | | | | | ▲ | | | | |
| Hansen 2006 | | | | | | | | ▲ | | ▲ | | ▲ |
| IMF Macroeconomic impact of high oil prices | | | | | | | | | | | | ▲ |
| Robert B. Barsky and Lutz Kilian 2004 | | | | | | | | | | | | ▲ |
| Energy modelling forum - SR Final Report | | | | | | | | | | | | ▲ |

# 3 Global energy demand

## 3.1 Introduction

The main factors which determine the quantity of energy consumed in any particular country include the number of people, their income level, the level and structure of production in the economy, the technology in place, the energy efficiency levels and energy prices. The mix of fuels consumed (i.e. energy derived from solid fuels, gas, oil, nuclear, renewables and derived energy sources such as electricity) is subject to many influences, including energy and environmental regulation and policy, prices of various fuels (influenced either by the market or government intervention), technological developments and the need for security of supply.

Depending on the relative influence of these factors in the various parts of Europe, quite different patterns of fuel mix have emerged, which in turn led to varying contributions to environmental impacts from the generation of energy from different sources.

This chapter addresses a comparative analysis of key variables in energy demand scenarios described in chapter 2, outlining an analysis of the methodology, the assumptions and outcomes of the studies scrutinised.

## 3.2 Demographic and macroeconomic assumptions

The main exogenous inputs to the energy consumption and production projections relate to world population and economic growth. In fact, these are the main drivers of energy demand and, at the same time, of energy future costs and technology performances.

### 3.2.1 Population development

Population growth affects the size and pattern of energy demand. The IEA projections are based on the projections contained in the United Nation report on World Population Prospects (UNPD, 2005). The International Energy Outlook by EIA uses the US Annual Energy outlook 2006 for the USA data and the same source as IEA for the other countries. WETO-H2 and “EC scenarios on high oil and gas prices” follow the same approach and the data sources for GDP and population trends are the same. The study of “EC Energy and transport scenarios trends to 2030” provides data only for EU-25 which is derived by Eurostat and UN-HABITAT (UN-HABITAT, 2005). Population trends in EU 25 from 2000-2030 are shown in Table 3.2 making reference to EUROSTAT estimations. As a result, the projections depicted in IEA and EIA reports do not differ considerably from each other. In WETO-H2 the differences in the growth rates are probably due to different regional breakdowns[10].

Table 3.1 World population growth, 2004 to 2030 (average annual growth rates)

| | IEA – WEO 2006 | EIA – IEO 2006 | WETO-H2 |
|---|---|---|---|
| OECD | 0,4 | - | |
| North America | 0,8 | 0,9 | 0.8 |
| United States | 0,8 | 0,8 | |
| Europe | 0,2 | 0,2 | 0.0 |
| Pacific | 0 | 0,1 | -0,1 |
| Japan | -0,2 | -0,2 | -0.1 |
| Transition Economies | -0,3 | -0,1 | |
| Russia | -0,5 | -0,5 | (*) -0.4 |
| Developing Countries | 1,2 | 1,1 | |
| Developing Asia | 0,9 | 0,9 | 0.5 |
| China | 0,4 | 0,4 | |
| India | 1,1 | 1,1 | |
| Middle East | 1,7 | 1,8 | 2.0 |
| Africa | 1,9 | 2,0 | 2.0 |
| Latin America | 1,1 | 1,1 | 1.0 |
| Brazil | 0,9 | 1,0 | |
| World | 1 | 1,0 | 0.9 |
| EU | 0 | - | - |

(*)The value of WETO-H2 for Russia refers to Community of Independent States.

Table 3.2 Population trends in the EU-25, 2000 to 2030

| | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| (Million in habitants) | | | | |
| EU 15 | 378.06 | 390.65 | 397.46 | 398.74 |
| EU 25 | 452.92 | 464.05 | 469.27 | 469.37 |
| (Annual growth rate) | 00/10 | 10/20 | 20/30 | 00/30 |
| EU 15 | 0.33 | 0.17 | 0.03 | 0.18 |
| EU 25 | 0.24 | 0.11 | 0.00 | 0.12 |

Source: EUROSTAT

### 3.2.2 Macroeconomic development

The rate of economic growth, measured by the growth in Gross Domestic Product (GDP), is a key determinant of the energy demand development. The outlook for medium- to long-term economic growth depends on the underlying demographic and expected productivity trends in

10 World breakdowns in WETO-H2 refer to geographical criteria providing numbers for Europe, CIS (Community of Independent States), North America, Latin America, Japan-Pacific, Asia (China, India and Rest of Asia), Africa -Middle East.

each economy. These in turn depend on population growth, labour force participation rates, productivity growth, and national savings and capital accumulation (EIA 2006).

Table 3.3 Global GDP growth rates by region 2004- 2030 assumed from different sources

| | WEO 2006 | IEO 2006 | WETO-H2 | EC – Trends to 2030 |
|---|---|---|---|---|
| OECD | 2,2 | | - | |
| North America | 2,4 | 3,1 | 2.2 | |
| USA | 2,3 | 3,0 | - | |
| Europe | 2 | 2,2 | 2.1 | |
| Pacific | 1,9 | 2.5 | 2 | |
| Japan | 1,4 | 1.4 | 2 | |
| Transition economies | 3,6 | 5.1 | - | |
| Russia | 3,4 | 3.9 | 4.1 | |
| Dev. Countries | 4,7 | 1,4 | - | |
| Dev. Asia | 5,1 | 3,6 | 3.1 | |
| China | 5,5 | 6.0 | - | |
| India | 5,1 | 5.4 | - | |
| Middle east | 4 | 4.2 | 3.2 | |
| Africa | 3,9 | 4.4 | 3.2 | |
| Latin America | 3,2 | 3.8 | 2.9 | |
| Brazil | 3 | 3.5 | - | |
| World | 3,4 | 3.8 | 4.0 | |
| EU | 2 | | | 1.67 (EU25) |

Source: TRT elaboration on data reported in the documents: EIA International Energy Outlook 2006, IEA – World Energy Outlook 2006, WETO-H2 2006, EC- Trends to 2030 (Update 2005). In WETO: Africa and Middle East are taken together, Japan and pacific are taken together, Brazil data is included in Latin America, USA is included in North America, China data is included in ASIA. CIS are the Community of independent states .

## 3.3 Energy demand projections

Three of the studies listed in the previous chapter provide world forecasts comparable with each other: World Energy Outlook (by IEA), International Energy Outlook (by EIA) and WETO-H2. For comparison, 2004 is used as the base year for all projections. It should be noticed that the regional breakdowns vary among the studies complicating the comparison (for example in WETO-H2, the projections are provided on a geographical basis, whereas in IEA and EIA figures are estimated by OECD, NON-OECD classifications). The EC-trends to 2030 has been also included as it uses a different energy model (PRIMES), although it provides data for the EU25 only.

These projections take into account a certain level of fuel prices that is directly linked to oil price assumptions (which are addressed later on in the chapter). The price of oil served as a reference price for other energy sources in all the reports considered. It should be mentioned that the long-term projections are based on demand driven variables such as real GDP growth, instead of short and medium term outlooks, where the production is based on studies of flow extraction, refinery capacity net of extraction decline rates.

The numbers of the 2004-2030 projections vary largely, with yearly growth rates ranging from 1.7% (in WETO-H2) to 2.0% and 2.6% in International Energy Outlook respectively reference and high growth case. All studies agree on the hypothesis that non-OECD energy demand will expand more rapidly than OECD energy demand, especially in non-OECD Asia; The largest differences amongst the reference cases are for China, where International Energy Outlook shows higher energy demand growth than IEA.

Table 3.4 Comparison of energy consumption growth rates by region 2004-2030 (average annual percent growth)

| | **IEO 2006 Reference case** | **IEO 2006 High growth case** | **WEO 2006** | **WETO-H2** | **EC Trends to 2030** |
|---|---|---|---|---|---|
| OECD | 1.0 | 1.3 | 0.9 | 0.6 | - |
| North America | 1.2 | 1.6 | 1.0 | 1.4 | - |
| Europe | 0.7 | 0.9 | 0.6 | 1.0 | 0.7 |
| Asia | 1.0 | 1.3 | 1.0 | 1.6 | - |
| Non-OECD | 3.0 | 3.8 | 2.4 | - | - |
| Europe and Eurasia | 1.9 | 2.5 | 1.3 | 1.0 | - |
| China | 4.4 | 5.1 | 2.6 | - | - |
| Other Non-OECD Asia | 3.1 | 3.9 | 2.7 | 2.4 | - |
| Middle East | 2.5 | 3.1 | 2.5 | 2.2 | - |
| Africa | 2.7 | 3.4 | 2.6 | 2.2 | - |
| Central South America | 2.8 | 3.4 | 2.6 | 2.0 | - |
| EU | | | 0.4 | - | |
| **Total World** | **2.0** | **2.6** | **1.8** | **1.7** | |

Source TRT elaboration on mentioned studies
Note: For WETO-H2 Africa and Middle East are included together; the value for Europe includes also non-OECD countries
EC Trends to 2030 makes reference to EU 25

The forecasts vary not only with respect to the level of energy demand, but also with respect to the mix of primary energy inputs. All forecasts provide energy consumption projections by fuel in 2030. In the International Energy Agency forecasts, worldwide energy consumption grows at a slower pace than in the corresponding reference case of the US EIA (1.6 % and 2 % per cent per year respectively). The oil consumption growth rate estimates of the studies are in line and in the reference cases range from 1.3% in World Energy Outlook 2006 to 1.6% in WETO-H2. The expectations for the other energy sources do differ: the largest discrepancies are in the estimations for nuclear power, where the WETO-H2 shows a consumption growth rate by 2.7%.

As expected, the *high growth case* for IEO 2006 provides higher growth rates for all the fuels with the exception of nuclear. In this case, the total energy consumption is expected to grow by 0.6% higher than in the reference case. The WEO 2006 by IEA stated that sufficient resources exist in order to meet the projected increases in demand through to 2030 for each form of energy described above.

Table 3.5 Comparison of World Energy Consumption Growth Rates by fuel 2004-2030

| FUEL | IEO 2006 Reference case | IEO 2006 High growth case | WEO 2006 | WETO-H2 | EC- Trends to 2030 |
|---|---|---|---|---|---|
| Oil | 1.4 | 2.0 | 1.3 | 1.6 | *0.0* |
| Natural Gas | 2.4 | 3.0 | 2 | 2.3 | *0.9* |
| Coal | 2.5 | 3.2 | 1.8 | 1.8 | *2.0* |
| Nuclear | 1.0 | 0.9 | 0.7 | 2.7 | *0.9* |
| Renewable/Other | 2.4 | 3.0 | 3.0 | - | *1.9* |
| **Total** | **2.0** | **2.6** | **1.8** | **1.7** | ***0.4*** |

Source TRT elaboration on mentioned studies
Note: For IEA, Renewable/other excludes traditional biomass.
Only EU 25 are considered in EC Trends to 2030

Table 3.6 Share of energy sources in total energy consumption according to WETO-H2 (in %)

| | 1990 | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|
| Solid fuel | 27,8 | 18,5 | 15,8 | 13,8 | 15,5 |
| Oil | 38,3 | 38,4 | 36,9 | 35,5 | 33,8 |
| Gas | 16,7 | 22,8 | 25,5 | 28,1 | 27,3 |
| Nuclear | 12,7 | 14,4 | 13,7 | 12,1 | 11,1 |
| Renewable | 4,4 | 5,8 | 7,9 | 10,4 | 12,2 |

Sources: WETO-H2

### 3.3.1 Oil demand development

Future total world oil demand is estimated on the basis of an assumed price path and future economic growth. Table 3.7 shows the projections of oil consumption growth assumed by these studies. The largest differences amongst the three forecasts are for North America. WETO-H2 projected an annual oil demand for North America that is 1 percentage point lower than in IEO 2006. In all studies most of the increase in oil demand comes from developing countries, where economic growth is expected to be high. China and the rest of developing Asia reach a 3.4% growth in WEO 2006 and 3.8% in IEO 2006, in line with their predicted rapid economic growth. Demand rises much more slowly in OECD countries, especially in Europe and the Pacific region. Beside the three reports, the “EC - trends to 2030” study provides a projection for EU 25 that shows a zero growth for oil demand in terms of average growth rates from 2004 to 2030.

Table 3.7 World oil consumption by region – Average annual growth rates 2004-2030

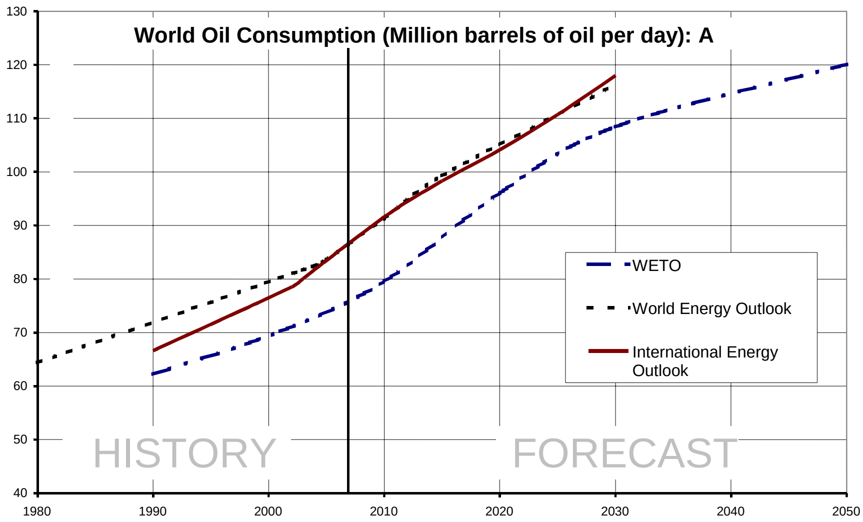
| | IEO 2006 | WEO 2006 | WETO-H2 |
|---|---|---|---|
| OECD North America | 1.2 | 0.9 | 0.2 |
| OECD Europe | 0.2 | 0.2 | 0.2 |
| OECD Asia | 0.5 | 0.3 | 0.7 |
| Russia | 0.9 | 1.0 | - |
| Non-OECD Asia | 3 | 2.9 | - |
| *China* | *3.8* | 3.4 | - |
| Middle East | 1.5 | 2.0 | 1.2 |
| Africa | 2.3 | 2.4 | - |
| Central and South America | 1.7 | 1.5 | 1.8 |
| **Total world** | **1.4** | **1.3** | **1.6** |

Source TRT elaboration on mentioned studies

The economies of non-OECD countries will remain more oil-intensive[11] than those of OECD countries. The transport sector absorbs 63% of the increase in global oil demand in 2004-2030. In the OECD, oil use in other sectors hardly increases at all. Most of the increase in non transport sector is met by gas, coal renewable and electricity. In non-OECD countries, transport is the biggest contributor to oil demand growth.

Worldwide oil consumption rises from 80 million barrels per day in 2003 to 98 million barrels per day in 2015 and then to 118 million barrels per day in 2030 (IEO 2006). According to WEO 2006 the global oil demand reaches 99 million barrels per day in 2015 and 116 mb/d in 2030. In WETO-H2 the world oil consumption reaches 108 mb/d in 2030 and 120 mb/d in 2050.

Figure 3.1 World oil consumption projections by different studies




Source: TRT elaboration on mentioned studies

[11] Measured by the amount of oil used per unit of gross domestic product (at market exchange rates) IEA 2006.

# 3.4 Transport demand

## 3.4.1 Introduction

The transport market today is almost entirely dependent upon oil-based fuels and is responsible for about 67% of the final oil demand in the EU. The dependency on imported liquid fuels amounts to about 72 % of the European oil consumption and may even increase up to 93 % by 2020, due to the depletion of the EU's own oil resources and an increasing energy demand.

Over the last years, several possible alternatives to replace oil based fuels have emerged such as Natural Gas (NG), Conventional Bio-fuels (Biodiesel and Bioethanol), Advanced Bio-fuels (Biomass to Liquids) and Hydrogen. In the short to middle term it is likely that bio-fuels and natural gas will play a major role while in the long term, hydrogen seems to be a promising option for a larger market share.

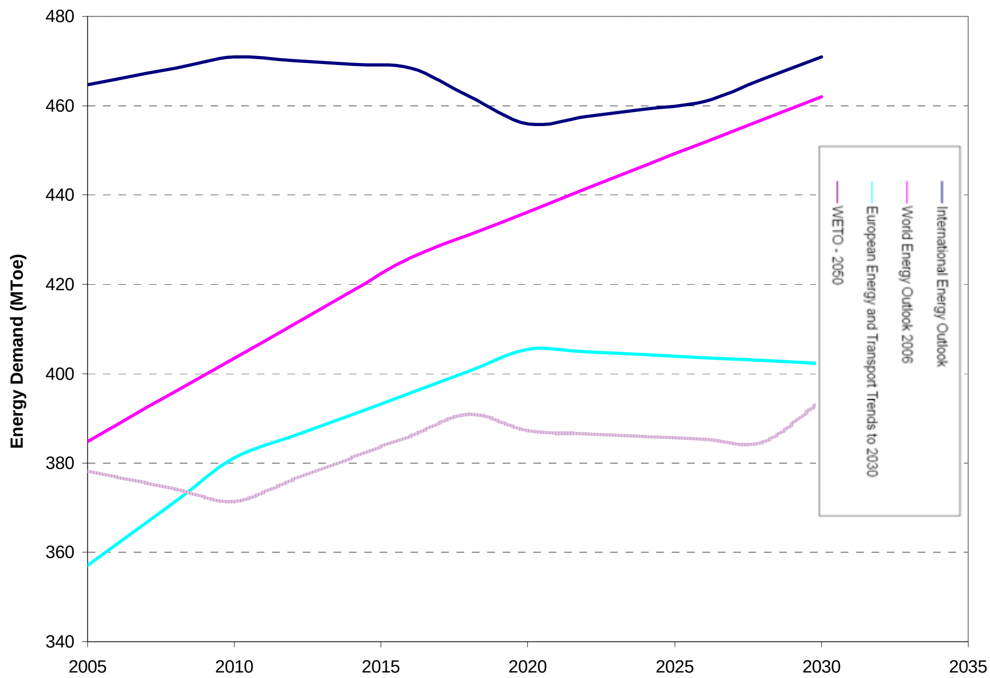
## 3.4.2 Transport energy demand development

There are several publications that forecast the relationship between energy prices and transport demand in both short term and long term policy models, namely European Energy and Transport Trends Up to 2030, based on the PRIMES forecast model, The World Energy Outlook by the International Energy Agency, based on the WEM model, and the International Energy Outlook by the Energy Information Administration, based on the NEMS model. Each of the reports combines historical data with forecasts based on market indicators.

As it can be seen from Figure 3.1 there is a consensus between expected increases in transport energy demand, approximately 10% between 2005 and 2030. However, the International Energy Outlook estimates a current energy demand of approximately 470 Mtoe, which shows negligible increases over the 25 year period.

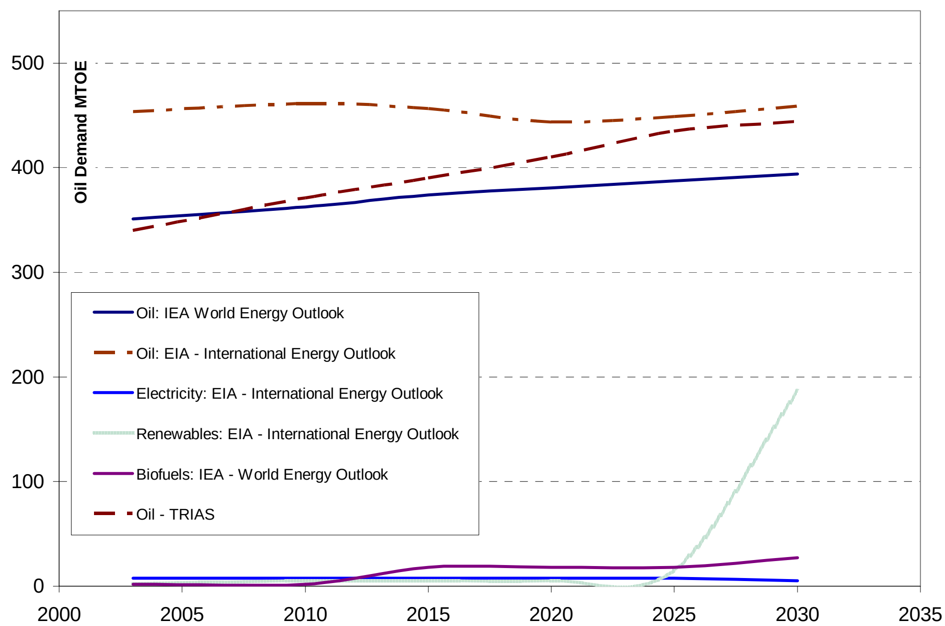
The publications also agree that alternative fuels will be heavily utilised within the next 10-15 years, particularly natural gas and renewable energies. However it is clear that oil derivatives will remain the dominant fuels in the transport sector. Figure 3.2, shows that oil will remain the dominant fuel in the transport sector. Other fuels exhibit small degrees of market penetration and negligible increases over the 25 year period. The International Energy Outlook shows that considerable interest in natural gas may occur towards 2025, possibly as a result of increases in oil price.

Figure 3.2 Total Transport Energy Demand in OECD Europe* Between 2005 and 2030




Source: TRT elaboration on mentioned studies

Figure 3.3 Energy Demand by Fuel Type in OECD Europe Between 2005 and 2030




Source: TRT elaboration on mentioned studies

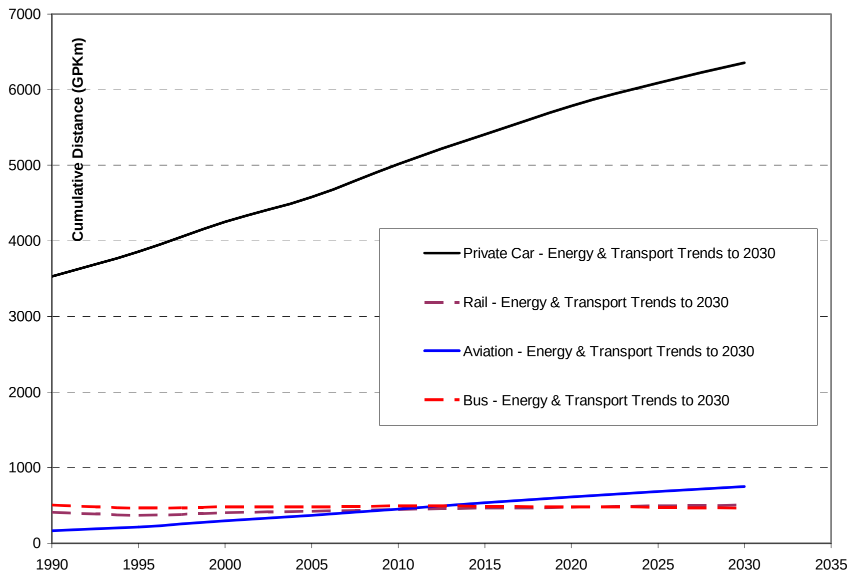
### 3.4.3 Passenger transport demand

According to the studies (Figure 3.7), the greatest increases in transport demand will occur in private motor-vehicle use. Other transport modes will remain constant or, in the case of rail, will tend to decrease.

According to the International Energy Outlook, the slowest increase in worldwide energy demand among the end-use sectors is projected for transportation, at 1.4 percent per year. In contrast, the *International Energy Outlook 2005* (*IEO- 2005*) reference case showed transportation energy use growing at the same rate as industrial energy use and faster than energy use in the buildings sectors.

When considering “alternative scenarios”, both the Commission's Energy and Transport Trends and the IEA's Outlooks reach similar conclusions; “new policies and cleaner technologies would achieve energy savings and promote less carbon-intensive fuels”. The OECD report predicts that this would eventually stabilise greenhouse gas emissions in the OECD countries by 2030.

Figure 3.4 Comparison of EU25 Transport Demand by Mode Between 2005 and 2030




Source: TRT elaboration on mentioned studies

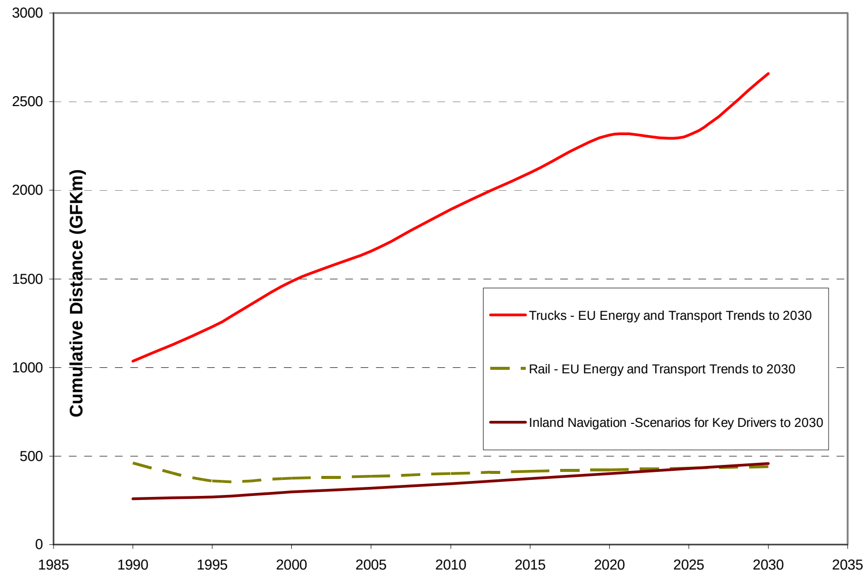
In the EU Energy & Transport Trends Alternative Policy Scenario, oil reductions in the transport sector account for about 60% of the total reduction in total oil demand. Energy demand in the transport sector reaches 2 800 Mtoe in 2030, about 300 Mtoe, or 10%, less than in the Reference Scenario (Table 9.3). The oil saved in transport amounts to 7.6 mb/d in 2030, equal to slightly more than the current production of Iran and the United Arab Emirates combined. Those savings have profound implications for oil import needs, as described in Chapter 7. Oil derivatives remain dominant for 90% of transport demand in 2030, reflecting the extent of the challenge of developing commercially viable alternatives to oil to satisfy the high level of demand. Because road transport currently accounts for about 80% of total transport energy demand, savings in this sector have a large impact on projected growth. In the Alternative Policy Scenario, demand for oil for road transport is 14% lower in 2030 than in the Reference Scenario.

Improvements in vehicle fuel efficiency, greater use of alternative fuels – mainly biofuels – and modal shifts (shifts to different forms of transport) explain this trend. Reduced demand for aviation fuels accounts for 11% of total savings in transport energy demand.2 OECD countries see a saving of 146 Mtoe, or 9%.

### 3.4.4 Freight transport demand

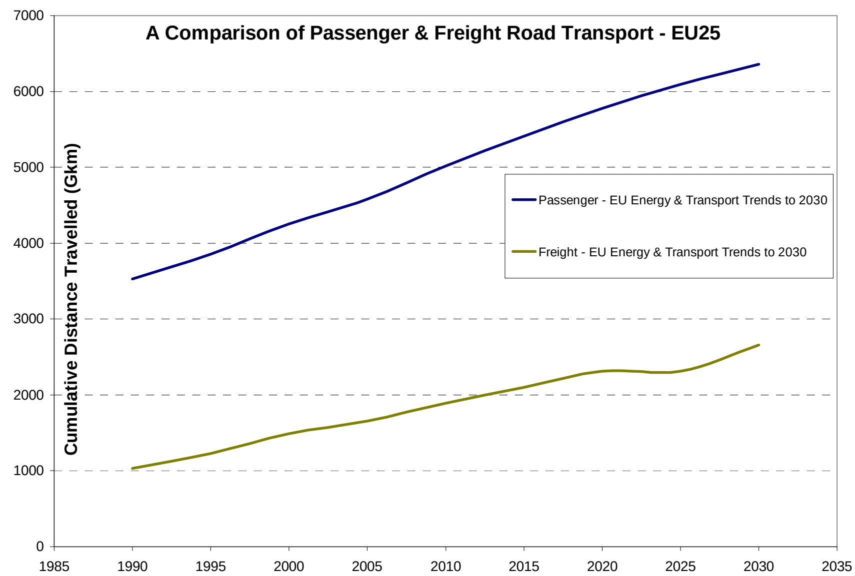
Both the 2006 World Energy Outlook and the EU Energy and Transport Trends predict that energy demand for freight transport is expected to increase at a slightly faster rate than energy for passenger transport. However, the World Energy Outlook predicts that it will account for no more than 40% of worldwide road transport energy demand in 2030. Additionally the EU Energy and Transport Trends predict an even lower share of 28% for road freight. Predictions from Energy & Transport Trends – Scenarios on Key Drivers show a continual increase in growth from 1990 to 2030.
It can be seen that road transport will continue to play a dominant role in freight. Between 1990 and 2030 total cumulative distance travelled increases from 1000 Gkm to approximately 2700 Gkm; an increase of 270%.
Rail shows a recovery from an initial early 90s dip, to a gradual increase of 3Gkm a year until 2030. Inland navigation increases differ between publications, with the Scenarios for Key Drivers showing a greater level of growth at 6.5 Gkm, compared to 1.3 Gkm for EU Energy and Transport Trends. The Scenarios on Key Drivers predict in a baseline scenario that, unless major new measures are taken by 2010 in the EU so that the Member States can use each mode of transport more rationally, heavy goods vehicle traffic alone will increase by nearly 50% over its 1998 level in EU-15.

## Figure 3.5 Freight transport activity forecast




Sources: TRT elaboration on mentioned studies

## Figure 3.6 Comparison of Road Based Freight and Passenger Demand Between 2000 - 2030




Sources: TRT elaboration on mentioned studies

# 4 Oil and Gas Supply

## 4.1 Oil reserves and resources

### 4.1.1 Terminology

The assumptions about oil and gas reserves and resources are critical because of their influence on market behaviour and also because several studies suggest that access to supplies to meet future increase in demand may be difficult.

Oil availability is conventionally measured in terms of Ultimate Recoverable Resources (URR), which is the total amount of a finite resource that may be obtained at the end of extraction or production process. The URR estimations performed by geologists are based on a weighted sum of the following components: *production to date, proved reserves, estimated recoverable resources*. The weights reflect the relative uncertainty of the components that are associated to. In more detail, the components include:

- *Production to date*. This is a historical empirical component with limited uncertainties if heterogeneity of "oils" is excluded. Its weight is normally set to one (100%);

- *Proved reserves*. These are quantities of petroleum that, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations. Proved reserves can be categorized as developed or undeveloped[12] and their weights are influenced by different factors[13]. It must be noted that the ex-post factor recovery of an oil physical resource is a strongly variable fraction whose median is about 35%. This variability is very large for small reservoirs, which are particularly frequent today. For this reason, some experts argue that 35% of volumetric geological evaluations of oil resource might have been reasonably used in the past with large size reservoirs, but today does not seem appropriate (Guseo, Della Valle, 2006). The United States Geological Survey proposes a very broad interpretation of these proven reserves, including in this component an additional term called "reserve growth" (USGS, 2000).

[12] If deterministic methods are used, the term reasonable certainty is intended to express a high degree of confidence that the quantities will be recovered. If probabilistic methods are used, there should be at least a 90% probability that the quantities actually recovered will equal or exceed the estimate.

[13] For more details see http://geology.cr.usgs.gov/pub/bulletins/b2172-a/. USGS scenarios are not based on a historical learning of dynamics in extraction (production) process, but on partially subjective averaging of the URR components (Guseo, Della Valle, 2006)

- *Estimated recoverable resources.* These are unproved reserves, which are based on geologic and/or engineering data similar to that used in estimates of proved reserves; but technical, contractual, economic, or regulatory uncertainties preclude such reserves being classified as proved. *Estimated recoverable resources* refer to undiscovered petroleum and are based upon subjective assessments with different degrees of probability, usually very small (e.g. 5%). USGS provides yearly three point estimates of undiscovered and inferred resources: the mean, a 5% lower bound, and a 95% upper bound with no price relationship[14]. According to the society of Petroleum Engineers and World Petroleum Congress (*World Petroleum Council*):

  - *probable reserves* are those unproved reserves which analysis of geological and engineering data suggests are more likely than not to be recoverable. In this context, when probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves;

  - *possible reserves* are those unproved reserves which analysis of geological and engineering data suggests are less likely to be recoverable than probable reserves. In this context, when probabilistic methods are used, there should be at least a 10% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable plus possible reserves.

There is another important distinction between conventional and non-conventional oil, which should normally be considered separately and distinguished from other sources of supply given that each has its own costs, characteristics and depletion profile. Oil is considered non-conventional if it is not produced from underground hydrocarbon reservoirs by means of production wells and/or it needs additional processing to produce synthetic crude. According to the IEA (World Energy Outlook 2006), the non-conventional oil includes the following sources, listed in order from the heaviest to the lightest: oil shales; oil sands-based synthetic crudes and derivative products; coal-based liquid supplies; biomass-based liquid supplies; gas-based liquid supplies.

From the considerations here above, it can be easily argued that the comparison of reserves and resources assessments among the various sources is complicated by differences in estimation techniques and assumptions among countries and companies. In particular, assumptions about prices and technology have a major impact on how much oil is deemed to be economically recoverable.

### 4.1.2 *Peakists* and *optimists*

The possibility that technology development and high oil process might have a major impact on the future development of oil production is one of the different points of view that divide the so-called *peakists* from the *optimists*.

[14] U.S. Geological Survey Bulletin 2172–A

The former believe that an energy crisis may not be far off; - in fact they predict that the world production might start to decline within the next few years, after reaching the oil peak. According to this view, as it has been postulated by geologist M. King Hubbert (M.K. Hubbert, 1956), the global oil production profile is a logistic or bell curve. Hubbert stated that the point of maximum production tends to coincide with the midpoint of depletion of the resource under consideration. In the case of oil, this means that when we reach the *Hubbert Peak*, we will have used half of all the recoverable oil that ever existed on the planet. The peak oil argument is supported with data indicating that new exploration finds are not sufficient to replace annual production and that the remaining oil resources present poor quality, high extraction costs or the energy input to convert it into usable energy is extremely intensive.

Table 4.1 Peak oil timing forecast

| **Projected Date** | **Source of Projection** | **Background & Reference** |
|---|---|---|
| 2006-2007 | Bakhitari, A.M.S - Guseo | Oil Executive (Iran) |
| 2007-2009 | Simmons, M.R | Investment banker (U.S.) |
| Around 2010 | Campbell, C.J | Oil geologist (ASPO) |
| After 2010 | World Energy Council | World Non-Government Org. |
| 2010-2020 | Laherrere, J. | Oil geologist (ASPO) |
| 2016 | EIA nominal case | DOE analysis/ information (U.S.) |
| After 2020 | CERA | Energy consultants (U.S.) |
| 2025 or later | Shell | Major oil company (U.K.) |
| 2020 | Michael Lynch | |

Source: TRT elaboration on mentioned studies

On the other side, the optimists believe on the strong contribution that could come from probable and possible resources. For instance, unconventional oil might largely contribute to total oil supply in the next future. According to current estimates (TOTAL 2006), the volume of unconventional crude that can technically be recovered is equivalent to all the oil reserves in Saudi Arabia[15].

The recoverable reserves estimates evolve with time and are subject to significant change, and also the impact of technological advances can be substantial in contributing to the overall resources. No less important are the impact of both oil price and demand on productive capacity.

Disregarding the presented points of view (either *peakist* or *optimist*), it is important to underline that there are widespread concerns about the reliability of oil and gas reserves data, and to a lesser extent on oil production data. Proven plus probable reserves estimates are confidential in all countries[16], with the exception of UK (DTI), Norway (NPD), and US (MMS) (Laherrère 2004). It is then obvious to suggest that oil companies and countries might be tempted to exaggerate their reserve as this can raise the price of oil company's stocks or, in the case of the OPEC countries, their production as this is correlated with the countries exports share.

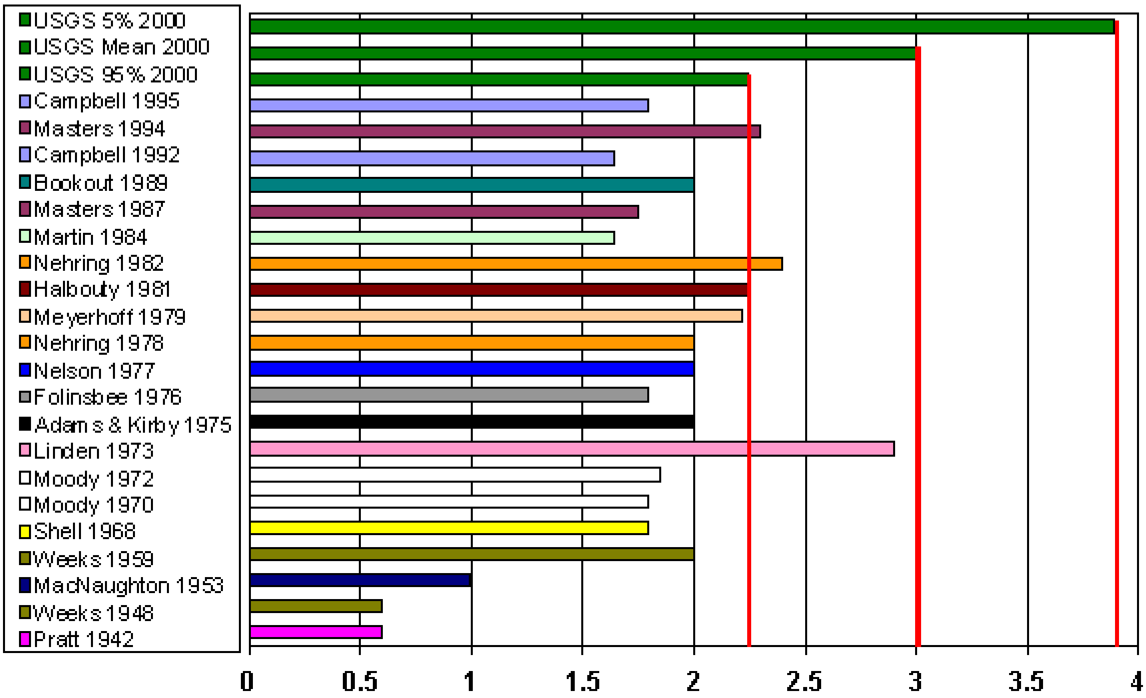
15 However, producing these unconventional resources calls for heavy investment and techniques that consume a great deal of energy and water.

16 In Russia, divulging data about oil (but not gas) reserves can be punished by 7 years jail.

### 4.1.3 World oil resources estimations

The figure 4.1 represents the published estimates of World oil ultimately recovery since 1942 to 2000. According to this figure it can be argued that the estimations are approximately the same from 1970 (2GBl). Only the last estimations performed by USGS seem to vary widely[17].

Figure 4.1 Published estimates of world oil URR - Ultimate Recoverable Reserves (Trillions of Barrels)




Source: USGS and Colin Campbell

17 Bardi U. www.aspoitalia.net

Table 4.2 Most recent world oil resources assumed from different sources (Bbl)

| | Year | Proved reserves | Estimated recoverable resources | Total |
|---|---|---|---|---|
| Oil and gas journal | 2006 | 1293 | | |
| BP | 2005 | 1200 | | |
| OPEC | 2005 | 1153 | | |
| World Oil | 2006 | 1119 | | |
| Lynch | 2005 | 1100 | | 2200 |
| Colin Campbell | 2006 | 790 | 140 | 930 |
| Jean Laherrere | 2006 | 800 | 200 | 1000 |
| USGS | 2000 | 1579 | 732 | 2311 |
| CERA | 2006 | 1000-1180 | 1350-2490 | 3350-4800 |
| WEO | 2000 | 1579 | 732 | 2300 |
| IEO base case | 2000-2006 | 1293 | 1668 | 2961 |
| WETO-H2 | | 1100 | 600 | 1700 |

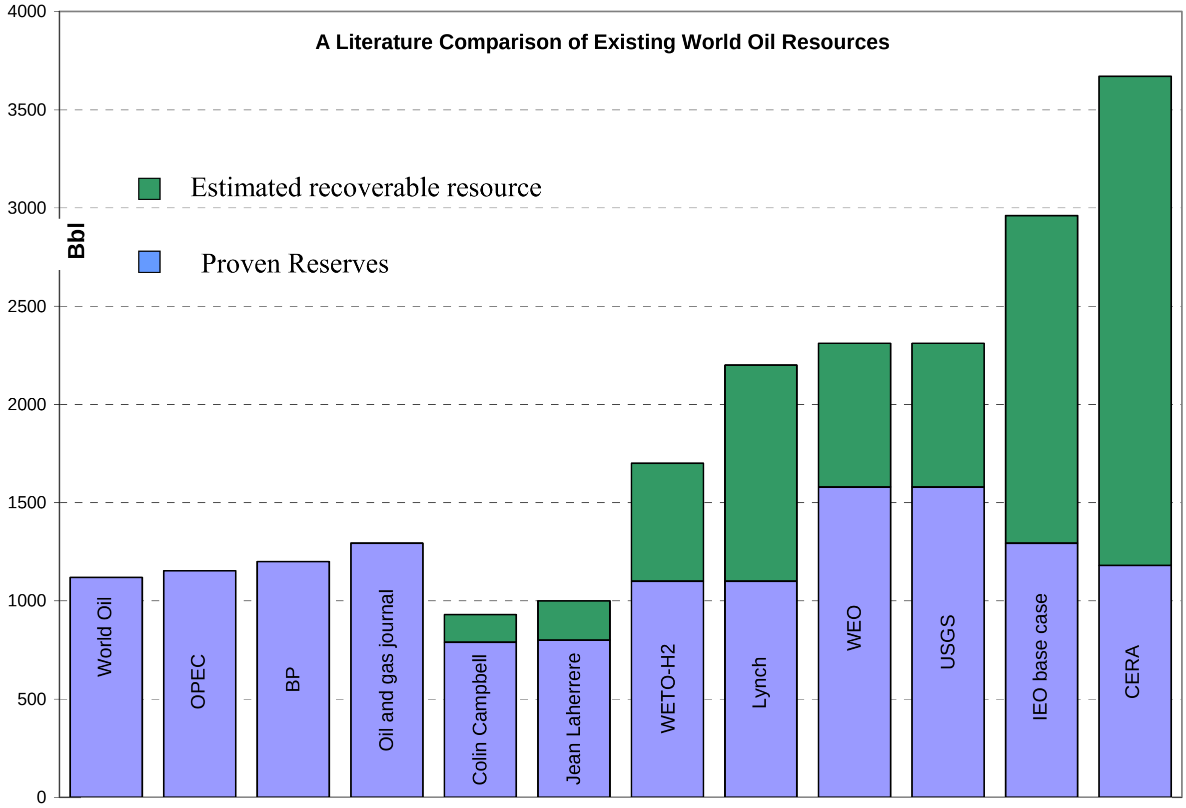
Source: TRT elaboration on mentioned studies
Note: IEO based its data on O&GJ for proved reserves and on USGS for estimated recouverable resources expressed as (reserve growth + undiscovered). WEO uses the same estimates of USGS – *World petroleum assessment 2000*.In WETO-2030 The core assumptions for the URR, are based on the USGS median estimates in each producing region considering revision made by Institut Francaise du Petrole

Table 4.2 gathers the estimations of world oil resources made by the organisations presented in chapter 2. Proven reserves and estimated recoverable resources where available are listed in the table, while details about some of the studies are presented later on in the text.

As already mentioned, the data reported can differ in some important assumptions; the types of oil taken into account (e.g. from 2002 the Oil and Gas journals included the *tar sands* in the oil estimations which evidently has a different oil depletion process) and the different definition of reserves and resources assumed. (A source of systematic error in the commonly accepted statistics is that the definition of reserves varies widely from region to region. Campbell 2001). The data regarding proven reserves provided by USGS also includes the reserve growth values that account for 688 Bbl (Mean Value). The Campbell estimates do not include heavy, deepwater and polar oils, and NGL. For CERA the two numbers provided refer to either conventional or non-conventional oil (see paragraph below). For BP, oil reserves include condensate and natural gas liquids. Canadian oil sands 'under active development' have also been included when deriving proved oil reserves in the most recent documents.

The proven reserves value reported in the table range from 790Bbl (Campbell) to 1579 Bbl USGS. The data published by OPEC, O&GJ, BP, and World Oil concerning proven oil reserves range from 1119 Bbl (World Oil) to 1293 (O&GJ).

Figure 4.2 A Literature Comparison of Existing World Oil Resources (Bbl)




Source: TRT elaboration on mentioned studies

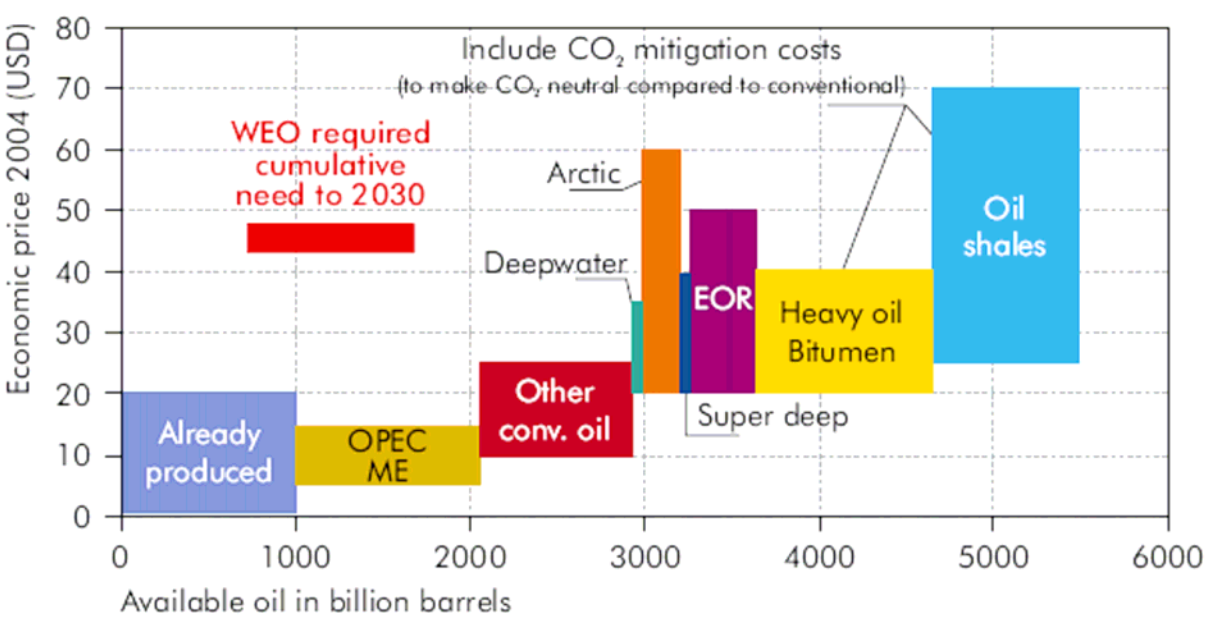
The table shows also different forecasts for estimated recoverable resources which refer to undiscovered fields. In this case, the data provided varies from 140 Bbl (Campbell) to 1350 Bbl (CERA) when only oil conventional is considered. As the figure 4.2 shows, this estimates present more evident differences in their numbers than in the proven reserves estimates.

The past showed that the oil that has been classified as resource will become finally reserve. The recoverable rate depends on technology, which in turn is influenced by the oil prices. The IEA in its Resource to Reserves study (2005) dealt with this issue; the study projects what magnitude of resources might be turned into reserves as function of oil prices, taking into account likely technological progress These estimates are illustrated in figure 4.3[18].

Non-unconventional oil has also been included in the estimates. According to some studies (CERA) it still can play an important role in meeting the energy demand in the future scenario.

[18] Currently, most companies base their investment decisions on a long-term price of USD 20 to USD 25 per barrel. The graph suggests that accepting a long-term price of, for example, USD 30/barrel would make an appreciable difference to the economic recoverability of large amounts of oil.

Figure 4.3 Oil cost curve, including technological progress: availability of oil resources as a function of economic price

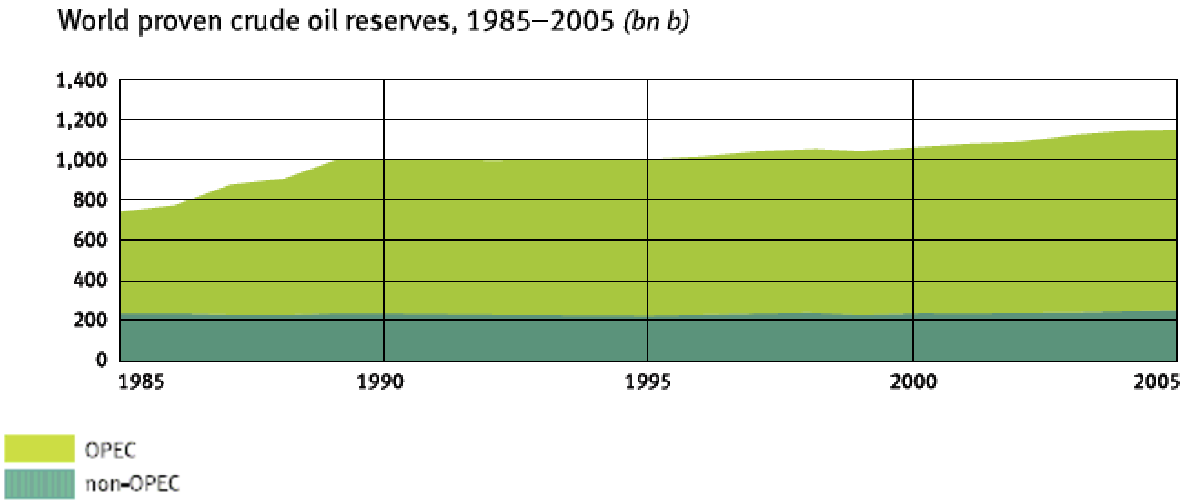



Source: IEA, Resources to Reserves, 2005

Figure 4.4 describes the world proven crude oil reserves as estimated by OPEC. Although all the studies differ in the figures, all agree on what the graph clearly states, that there is a large difference in the potential between OPEC and Non-OPEC countries (see also Figure 4.4 from BP in which the data on reserves are split by region). The OPEC report states that the proven OPEC reserves represent approximately 78% of the world total (1153 Bbl). The oil and gas journal estimations in the Figure 4.3 show proven oil reserves data split by countries with greatest remaining reserves. The reserves-to-production ratios are also shown in the figure providing information on the oil depletion time expressed in years. This value should be considered rather indicative given that the oil production is not constant over the time. Figure 4.7 shows how estimates of the official world oil reserves and production made by BP have changed during the period 1961-1995.

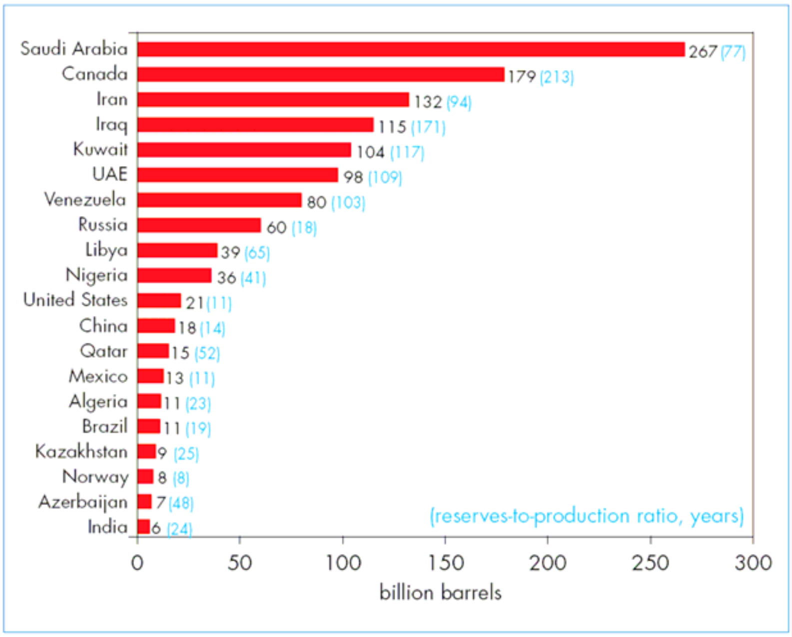
Oil production estimations are certainly crucial in order to determine the future oil availability. The production has been modelled in the IEO, for which the model used is summarised in Figure 5.1 and a similar approach is also used in WEO but no data is provided in this report. Only in the case of WETO-H2 were numerical results provided at the end of this chapter. The global oil production forecasts have also been performed and data is available for the models developed by Campbell, Laherrere and Bakhtiari. While actual data concerning the oil production is available for BP and OPEC.

Figure 4.4 Proved reserves at 2005 by OPEC (billion barrels)



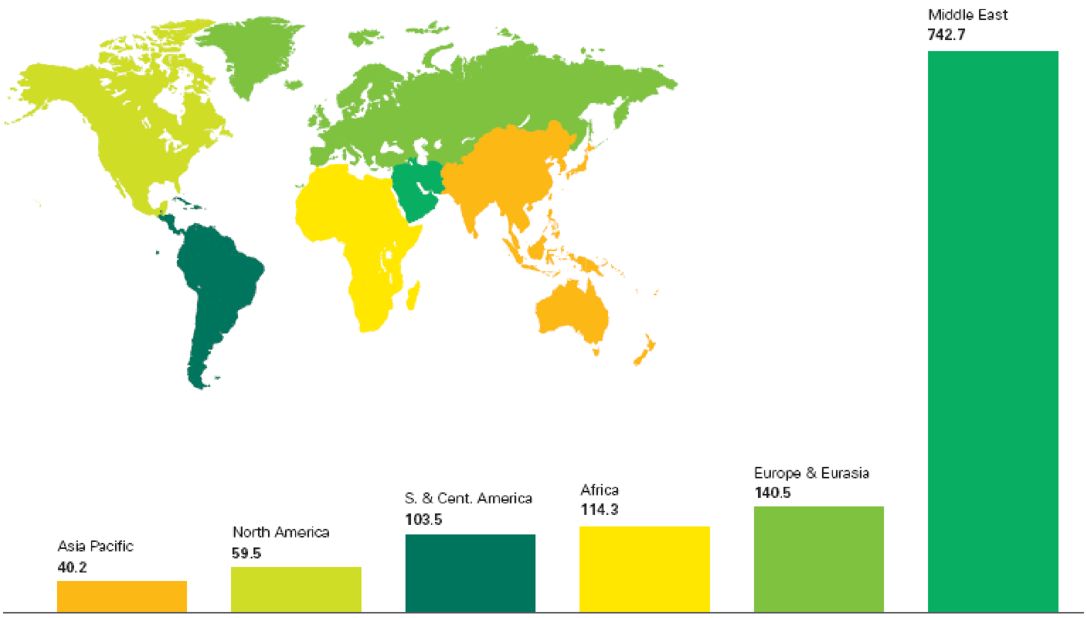

Source: OPEC

Figure 4.5 Top twenty countries' proven oil reserves by Oil and Gas Journal, end-2005



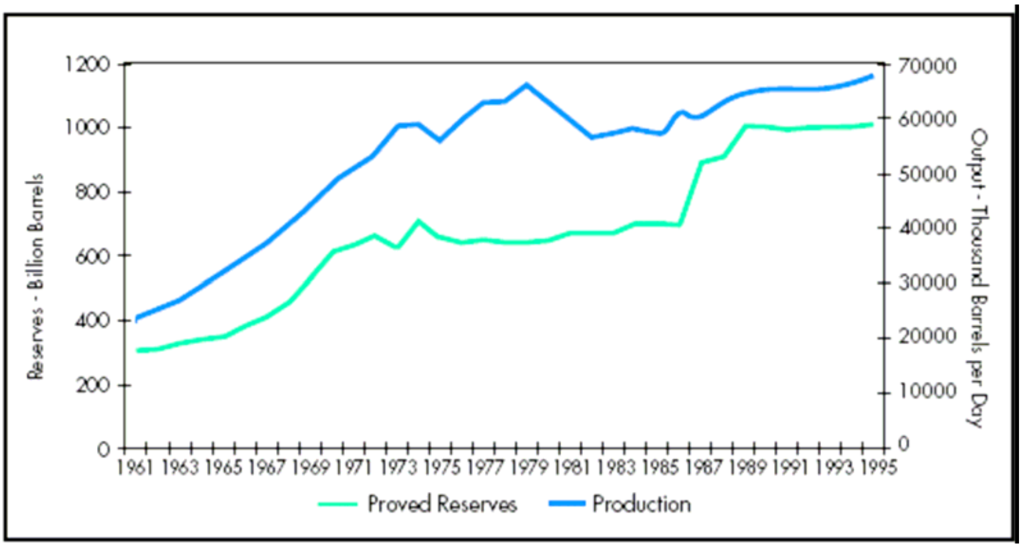

Note: Canada includes proven non-conventional reserves.
Source: *Oil and Gas Journal* (19 December 2005).

## Figure 4.6 Proved reserves at 2005 by BP (billions barrels)




Source: BP Statistical Review of World Energy, 2005

## Figure 4.7 World oil official (proved) reserves & production between 1961 and 1995




Source: BP Statistical Review of World Energy, 1997.

## CERA

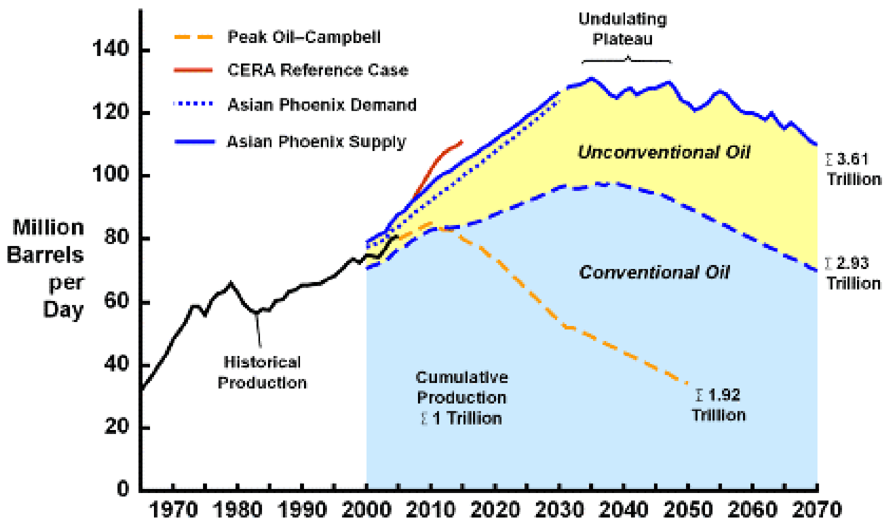
CERA projection is based on the firm's analysis of fields currently in production and those yet-to-be produced or discovered. The conventional and unconventional oils are included together in their estimations. They state that global production will follow an "undulating plateau" for one or more decades before declining slowly. During the plateau period the demand growth will need to be met by non-traditional and unconventional liquid fuels. According to CERA analysis, the start of undulating plateau will occur after 2020, allowing time for developing viable energy alternatives.

Table 4.3 Global resources, conventional and unconventional by CERA

| | Cumulative Production | OPEC Middle East | Other Conventional | Deepwater | Arctic | Enhanced Oil Recovery | Extra Heavy | Oil shale Extract | Exploration Potential | Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| Rest of the world | 813 | 662 | 378 | 50 | 110 | 510 | 277 | 200 | 660 | 3660 |
| United States | 234 | - | 19 | 8 | 5 | 76 | - | 500 | 83 | 925 |
| Canada | 31 | - | 7 | 3 | 3 | 6 | 167 | 4 | 15 | 236 |
| **Total** | **1078** | **662** | **404** | **61** | **118** | **592** | **444** | **704** | **758** | **4821** |

Source: United States Geological Service, World Petroleum Assessment 2000, CERA, National Energy Board Canada

Figure 4.8 Undulating plateau versus peak oil



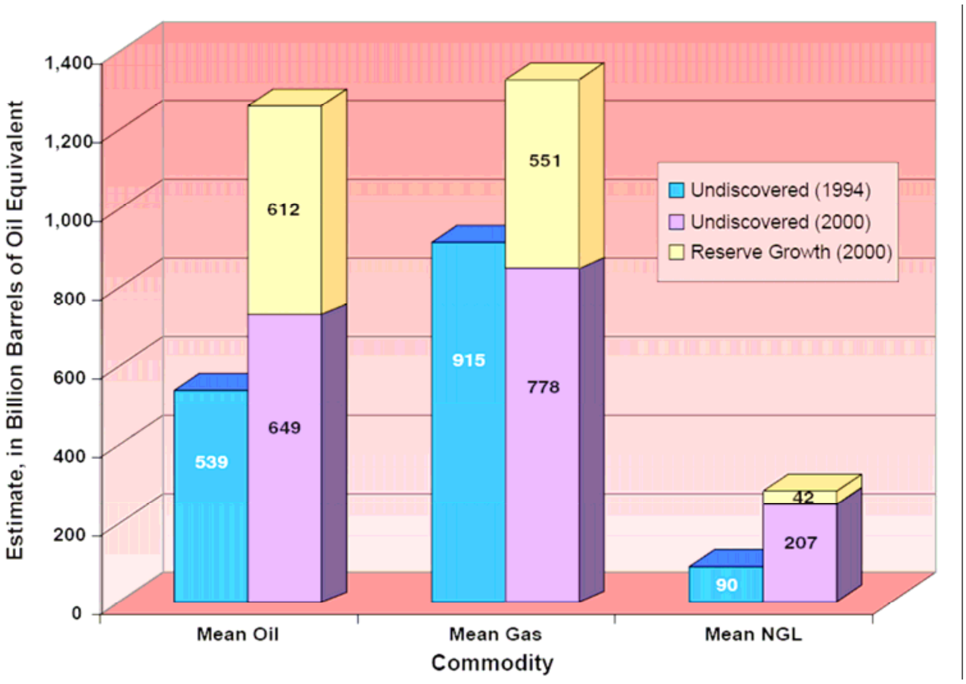

Source: CERA, 2006

**USGS**

According to the mean case scenario of US Geological Survey, undiscovered conventional resources that are expected to be economically recoverable could amount to 880 billion barrels, including natural gas liquids, or NGLs (USGS, 2000). Together with reserves growth and proven reserves, remaining Ultimately Recoverable Resources are put at just under 2300 billion barrels.

The World Petroleum Assessment 2000 contains the greatest volumes of undiscovered conventional oil in the areas of Middle East, northeast Greenland Shelf, the West Siberian and Caspian areas of the Former Soviet Union, and the Niger and Congo delta areas of Africa. Significant new undiscovered oil resource potential was identified in a number of areas with no significant production history, such as northeast Greenland and offshore Suriname. Figure 4.9 compares the 1994 and 2000 USGS world estimates exclusive of the U.S. for undiscovered conventional oil, gas and NGL in billion barrels of oil equivalent.

Figure 4.9 Comparison of 1994 and 2000 USGS world estimates exclusive of the U.S.




Source: World Petroleum Assessment 2000.

Compared to the last USGS world petroleum assessment (Masters and others, 1994, 1997), undiscovered volumes from the year 2000 assessment (exclusive of the U.S.) are 20 percent greater for oil, 14 percent smaller for gas, and 130 percent greater for NGL. The large estimated volumes of oil, gas, and NGL from reserve growth in this assessment represent a resource category not quantitatively assessed previously for the world by the USGS. The volume of undiscovered oil estimated in this assessment is larger than that of the 1994 assessment, due in part to larger estimates for the Middle East and Atlantic offshore portions of South America and

Africa. However, in some areas the estimated volumes of undiscovered oil were smaller, particularly for Mexico and China.

The volume of undiscovered gas estimated in the year 2000 assessment is smaller than that of the previous world assessment mainly because of smaller estimates for arctic areas of the Former Soviet Union, some basins in China, and the Alberta Basin of Canada. The volume of undiscovered NGL estimated in this assessment is much larger than that of the previous assessment because of more detailed analysis, coupled with the incorporation of co-product ratios into the assessment calculations.

### POLES estimates for "WETO" and "Scenarios on high oil prices" studies

A key feature of the POLES model is its detailed simulation module for the oil and gas discovery and development process, which is in particular essential to the endogenous process of international oil and gas price determination. In broad terms, the logic used in order to model oil and gas supply and price is based on the following sequence:

- the Ultimate Recoverable Resources (URR) is derived from the US Geological Survey (USGS) estimates, but is modified over the projection period in order to account for the impact of increasing recovery rates (which are assumed to be dependent on the oil and gas prices);
- discoveries depend on the drilling effort (also oil and gas price dependent) and the reserves are equal to the total discoveries minus the past cumulative production;
- for all regions except the Gulf, the production depends on a price dependent "reserve on production" or R/P ratio;
- the international prices depends, in the case of oil on the world R/P ratio (including non conventional oil), and for gas on regional R/P ratios as well as of an indexation term to the oil price that can be modified according to the scenario examined.

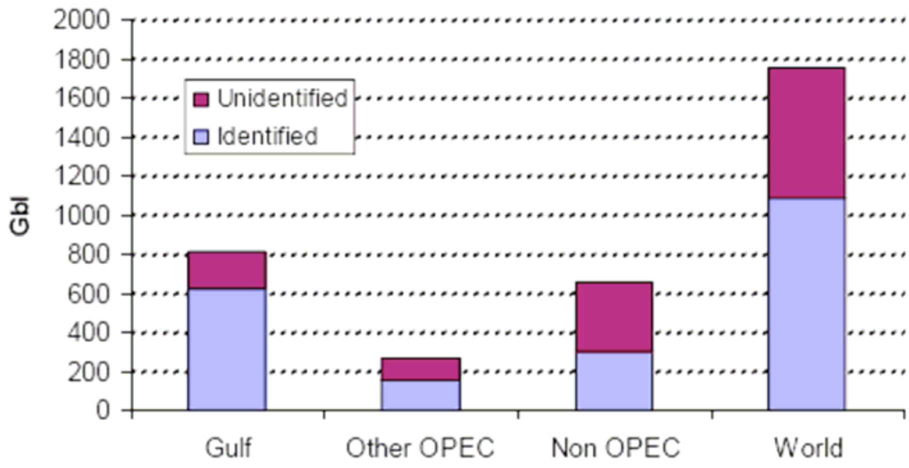
Table 4.4 POLES model estimates of oil and gas reserves (Bbl and growth rates)

| | **1990** | **2001** | **2010** | **2020** | **2030** |
|---|---|---|---|---|---|
| Oil reserves | 139,2 | 160,1 | 213,8 | 192,6 | 176,8 |
| Gas reserves | 121 | 146 | 203,8 | 223,4 | 228,7 |
| | **1990/2001** | **2001/2010** | **2010/2020** | **2020/2030** | **2001/2030** |
| Oil reserves | 1,28% | 3,27% | -0,99% | -0,9% | 0,33% |
| Gas reserves | 1,72% | 3,78% | 0,92% | 0,24% | 1,51% |

Source: POLES

According to oil reserves estimations made both in scenarios on high oil and gas prices and WETO-H2, the baseline scenario world oil reserves will expand significantly between 2001 and 2010 (+33.5%). Beyond 2010, as the world production level exceeds the rate of additional discoveries, world reserves will decline slowly, exceeding nevertheless in 2030 the 2001 level by 10.4%. World gas reserves also exhibit a significant growth between 2001 and 2010 (+39.6%) but slow down thereafter. However, even in the long run that annual production levels remain below additional discoveries and consequently gas reserves exhibit a further increase reaching +56.7% from 2001 levels in 2030.

Figure 4.10 Identified and unidentified oil reserves by POLES model




Source: WETO-H2

### 4.1.4 Oil production in WETO-H2

Cumulative production of oil today is around 900 Gbl. The assumption of the WETO-H2 study is that there are 1700 Gbl remaining, of which almost 1 100 Gbl has been discovered. Of these 1700 Gbl, about 1000 Gbl (including identified and unidentified resources) are in OPEC countries. The remaining recoverable resources represent 60 years of present production of conventional oil.

The oil production profile in the WETO-H2 reference case is largely consistent with this prognosis for the world oil system:

- until 2010, non-OPEC production increases slightly because of developments in the CIS; after that year non-OPEC production declines;
- the production of conventional oil in the world reaches a plateau at 100 Mbd in 2030 and then is stable until 2050; this occurs despite a rapid increase of capacity in the Gulf after 2010;
- production in both the Gulf and the rest of OPEC doubles from now until 2040 and then almost stabilises until 2050;

- production of non-conventional oil, mostly from extra-heavy oil and tar sands, becomes competitive; it provides nearly 28 Mbd in 2050, comparable to about 60% of the increase in total oil consumption from today to 2050.

According to the WETO-H2 study, in the short-term, market behaviour will be much influenced by the lack of surplus production capacity and by the peak in production from non-OPEC countries (that might be delayed by some production increase from the CIS). In the medium-term, the critical concern will be the extension of OPEC's countries production capacities well beyond their historic maximum (i.e. approximately 32 Mbd). In the long-term, the peak in OPEC and Gulf production will constrain the consumption of oil, even if non-conventional oil is developed strongly (as in the Reference case).

# 5 Oil prices development

Crude oil prices behave much as any other commodity, with price fluctuating when a shortage or oversupply occurs. The crude oil price cycle may extend over several years responding to changes in demand as well as OPEC and non-OPEC supply. The way in which the oil prices are determined, varies within the studies, nevertheless the oil prices are modelled in every study using the following inputs:

1. ultimate Resource Recovered;

2. commodities demand growth (depending on GDP and population);

3. oil production.

Therefore, energy prices are modelled in most studies primarily as a consequence of oil supply and demand. Nevertheless, it is generally thought that another factor such as limited production capacity can dictate prices. The current high oil price is a consequence of systematic under-investment that has eroded the spare capacity on the supply side (Cor Van Kuijsdijk 2005).

Reference scenario projections of the World Energy Outlook 2006 by IEA are based on the average retail prices of each fuel used in final consumption, power generation and other transformation sectors[19]. The fossil fuel price assumptions are based on those value needed to meet the projected demand over the period analysed[20]. In case of geopolitical tensions or major supply disruptions, the IEA in its report includes the possibility of much higher levels of oil prices than those projected.

A similar approach is followed by EIA with its International Energy Outlook 2006 for determining the prices. These are derived in an iterative way, starting from an oil price base assumption: the starting value, which is based on the average price of imported low-sulphur, light crude oil to U.S. refiners, is revised either upward or downward depending on whether the price assumed is able to meet the future total world oil demand or not. OPEC is assumed to be willing to meet the portion of global oil demand not met by non-OPEC producers at the given prices. The likelihood that OPEC producers would supply this residual demand at the assumed price path is based on estimates of total OPEC oil resources and the apparent preferred production levels of key OPEC members. This means that the production of OPEC countries is not directly influenced by the assumed oil import price as they have enough spare capacity to meet the worldwide oil demand and lower oil production costs than non-OPEC producers.

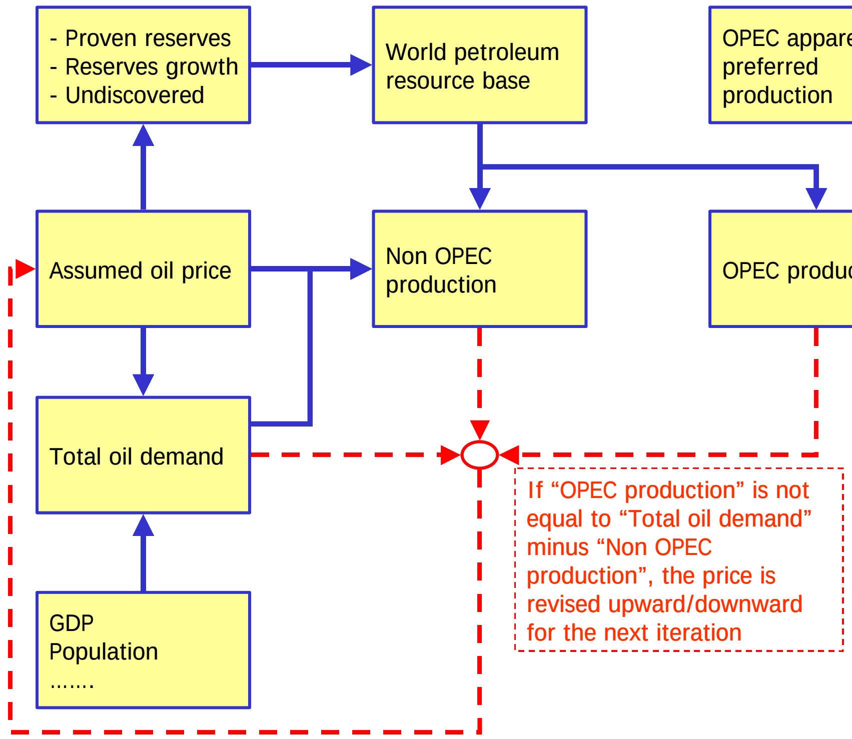
Once the base case oil price trends and composition of world oil supply are determined, the same iterative approach is used to determine high and low world oil price cases. In the first case, worldwide crude oil resources were assumed to be 15% less than in the reference case, whereas

19 Tax rates and excise duties are assumed to remain constant over the projected period.

20 Although the price paths show smooth trends, in reality prices are likely to stay volatile.

in the latter resources are assumed to be 15 % larger. According to these dynamics it is possible to determine the composition of the World supply for each price levels.

Figure 5.1 EIA model for oil production and price calculation



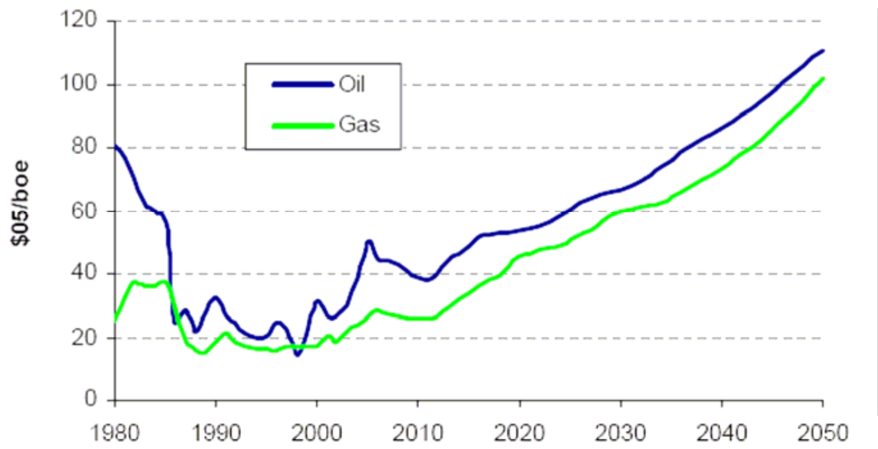

Source: TRT elaboration on NEMS model (IEO 2006)

In the International Energy Outlook 2006, a business-as-usual oil market was assumed, with no disruptions in oil supply, such as war, terror, weather, geopolitics etc. It was also assumed that all non-OPEC oil projects that show a favourable rate of return on investment would be funded and that peaking of world oil production is not anticipated until after 2030, i.e. for the period out to 2030, there is sufficient oil to meet worldwide demand.

In WETO-H2 study, a principal feature of the POLES model is that it estimates international prices for oil, gas and coal, based on an explicit description of the fundamentals of each international market and a detailed representation of the reserve and resource constraints. The model calculates a single world price; the oil market is described as "one great pool". It depends in the short-term on variations in the rate of utilisation of capacity in the Gulf countries and, more importantly, in the medium and long-term on the average Reserve-to- Production ratio across the world. The price of gas is calculated for each regional market; the price depends on the demand, domestic production and supply capacity in each market. There is some linkage to oil prices in the short-term, but in the long-term, the main driver of price is the variation in the average Reserve-to-Production ratio of the core suppliers of each main regional market. As this ratio decreases for natural gas as well as for oil, gas prices follow an upward trend that is similar in the long-term to that of oil. The average price of the key suppliers is derived from variations in mining and operating costs (that are a function of the increase in per capita GDP and of a productivity trend) and from the capital and transport costs (both depending on the simulated production increases, as compared to a "normal" expansion rate of production capacity).

Figure 5.2 illustrates the resulting trajectory of prices in WETO-H2: the price of oil rises to 2006, falls briefly to 40 $/bl towards 2010 and then increases to more than 60 $/bl in 2030 and to nearly 110 $/bl in 2050 as resource constraints become determinant. This price level is needed, not so much to stimulate supply alternatives, which are in most cases already competitive, but to curb the trend in world oil demand, which would otherwise be unsustainable. The projections of oil prices in "EC trends to 2030" derive also from the output of the POLES model and are therefore similar.

Figure 5.2 Prices of oil and gas from the Reference projection (WETO-H2)




Source: WETO-H2

Table 5.1 International price assumptions (Average border prices) EU25

| | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| Crude oil | 31.3 | 44.6 | 48.6 | 57.6 |
| Natural gas | 16.8 | 33.9 | 37.0 | 44.7 |
| Hard coal | 8.4 | 12.5 | 14.1 | 14.9 |

Source: POLES (EC-TRENDS to 2030)

Table 5.2 International price assumptions (annual growth rate)

| | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|
| Crude oil | -0.34 | 3.59 | 0.76 | 1.82 |
| Natural gas | -0.88 | 7.29 | 0.89 | 1.91 |
| Hard coal | -5.86 | 4.04 | 1.18 | 0.58 |

Source: POLES (EC-TRENDS to 2030)

## 5.1 Comparison of oil prices assumed by different studies

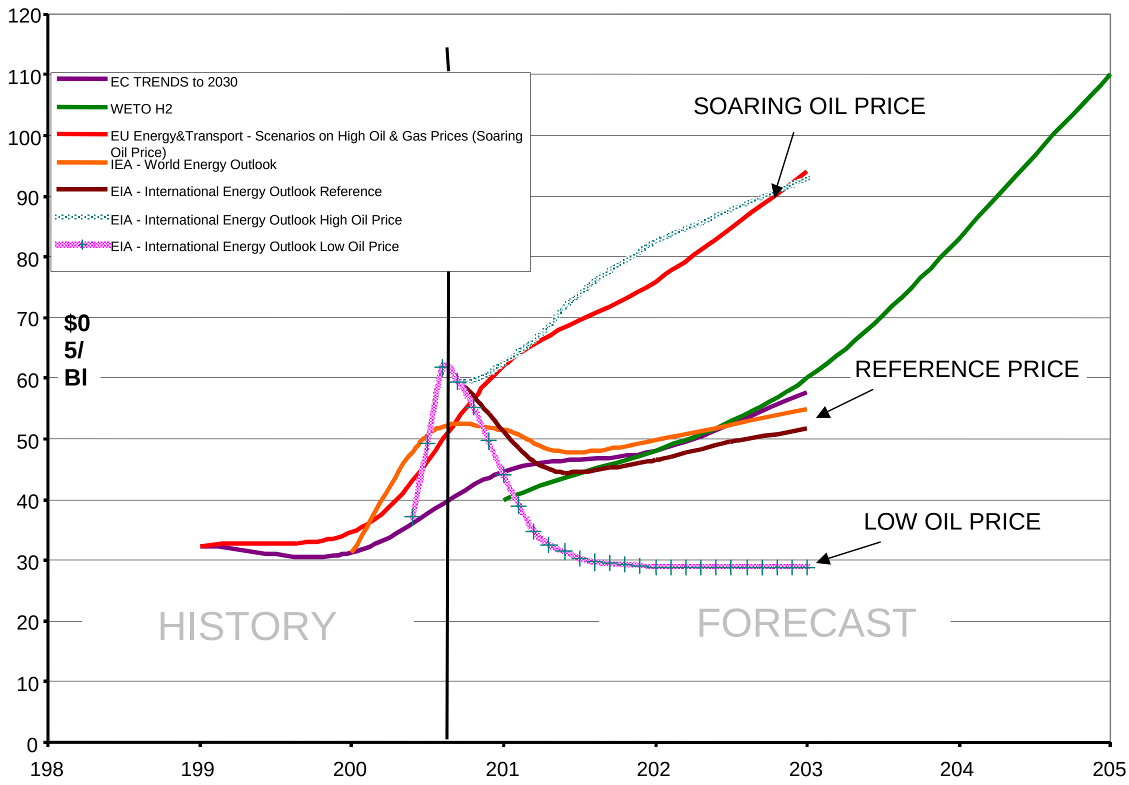
The average IEA crude oil import price, a proxy for international oil prices, was $51 per barrel in 2005. It is assumed to average slightly over 60% per barrel through 2007, and then decline to about $47 by 2012 (WEO 2006). In WETO-H2, oil and natural gas prices on the international market increase steadily and reach 110 $/bl for oil and 100 $/boe for gas in 2050. The high prices mostly reflect the increasing resource scarcity. The IEO considers three scenarios according to different assumptions about world oil supply; in the low world oil price, reference, and high world oil price cases, average world oil prices in 2030 are $29, $52, and $93 per barrel, respectively.

Table 5.3 World International oil prices assumed by different studies (imported crude oil $ 2005/Bl)

| | 2010 | 2030 | 2050 |
|---|---|---|---|
| IEO (low oil price scenario) | 44 | 29 | - |
| IEO (reference case) | 52 | 52 | - |
| IEO (high oil prices scenario) | 63 | 93 | |
| WEO | 52 | 55 | - |
| WETO-H2 | 40 | 60 | 110 |
| TRENDS TO 2030 | 45 | 58 | - |
| EC-Scenarios on H&O prices(reference case) | 55 | 58 | - |
| EC-Scenarios on H&O prices(soaring scenarios) | 62 | 99 | - |

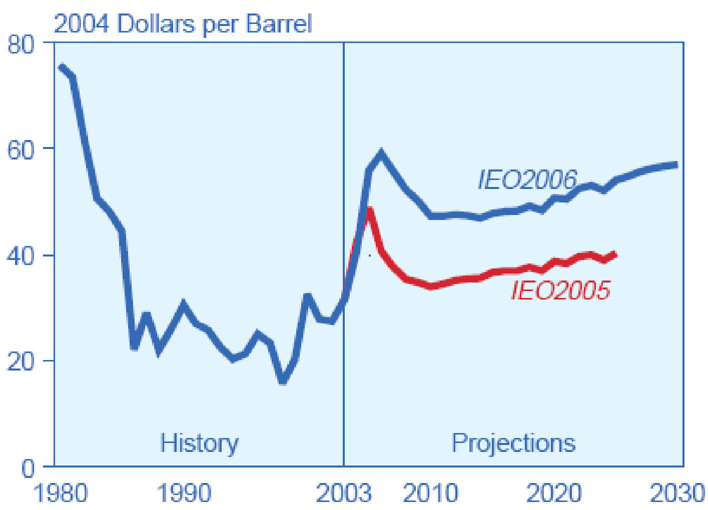
Source: TRT elaboration on mentioned studies
Note: for IEO (real 2004 dollars)

## Figure 5.3 Estimated World Oil Prices Between 1990 and 2050 (real $ 2005)




Source: TRT elaboration on mentioned studies

## Figure 5.4 Comparison of IEO2005 and IEO2006 World Oil Price Projections, 1980-2030




Source: IEO 2006

Oil price projections have been adjusted upwards by the IEA in its WEO 2006 and by EiA in the IEO 2006 compared to the previous publications. The figure shows that the oil prices in IEO 2006 are assumed to be 35 percent higher than projected in IEO2005[21]. However, it should be mentioned that the oil prices assumed in the IEO 2007 recently released by EIA, are the same as those in IEO 2006.

### 5.1.1 Net oil disruption impact on demand and supply sides

In this paragraph the consequences of a supply disruption on demand and supply side will be outlined. A reference is made to econometric studies analysed by the Energy Modelling Forum report (Hunlington 2006). In the last analysis, an estimation on how the oil price may vary as consequence of a net oil disruption will be provided.

Gasoline accounts for much of the world's current oil consumption. Recent econometric gasoline demand studies, surveyed by Goodwin, Dargay and Hanly (2004) and Graham and Glaister (2004), confirm previous results that gasoline consumption in many different countries declines by –0.2% to –0.3% during the first year after a 1% price increase. Since recent crude oil prices are approximately 40% of gasoline prices, the appropriate price response for crude oil will be about –0.08% to –0.12%. This estimate is also consistent with the demand response (–0.08%) from a recent econometric estimate of total crude oil consumption in 96 different countries (Gately and Huntington, 2002). This crude oil demand estimate includes the response of all petroleum products rather than gasoline alone.

The response of oil production to price changes is controversial; most econometric studies that focus on the United States frequently find an insignificant or negative response between oil prices and production (Dahl and Duggin, 1996, 1998). Nevertheless, according to a number of different oil market models that participated in EMF study, a proxy for the price elasticity for supply has been set by +0.05%. This estimation responds to the fact that it is unlike that oil production does not increase as consequence of a high oil price.

Table 5.4 shows the effect of 1MMBD net oil disruption on crude oil prices according to both impact on demand and supply sides. Reported are the price changes associated with lower and upper bounds on the supply and demand elasticities[22]. In boldface the *best guess* made by EMF is reported (EMF SR 9 Final report).

[21] IEO2006 oil price paths reflect a reassessment of the willingness of oil-rich countries to expand production capacity as envisioned last year. It does not represent a change in the assessment of the ultimate size of the world's petroleum resources but rather a lower level of investment in oil development (IEO 2006).

[22] These bounds have been constructed to reflect the uncertainty associated with any reported econometric estimate as determined by the standard error associated with the coefficient. Since the estimates guesses from a range of different studies, these ranges must be viewed as approximate at best.

Table 5.4 Effect of 1 MMBD net oil disruption on crude oil prices

| | | Supply Elasticity | | |
|---|---|---|---|---|
| | | *0,025* | *0,05* | *0,075* |
| **Demand elasticity** | *-0,04* | $10,53 | $7,6 | $539 |
| | *-0,08* | $6,52 | ***$5,26*** | $4,42 |
| | *-0,12* | $4,72 | $4,03 | $3,51 |

Source: EMF final report

## 5.2 Gas prices scenarios

While the oil market is rather integrated at global level, the markets of gas and coal show a strong regional basis. The reason lies on the high transportation costs of gas and coal relative to their production costs.

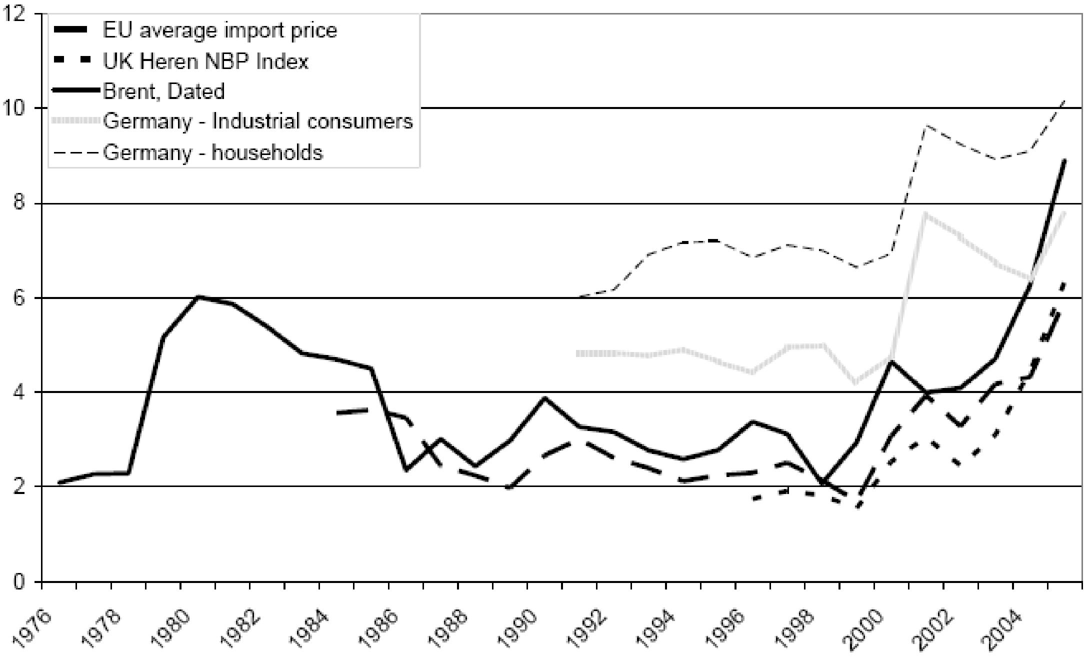
Most of the studies considered derived the Natural Gas demand from a gas price assumed which is linked to the oil import price. In fact, in the past gas prices have followed oil prices rather closely. This assumption is also fairly plausible if consider the existence of long-term gas selling contracts in which the gas price is linked to the oil price evolution. The figure below compares the oil price with some indices of international natural gas prices relevant for Europe.

The "European Energy and Transport - scenarios on high oil and gas prices" study does not exclude an alternative development of the gas prices somewhat decoupled from oil prices. The two alternative scenarios considered are:

- "Medium gas and soaring oil prices" case which assumes a higher economic growth in parts of Asia (China, India and other Asian developing countries) in combination to relatively less abundant resources than in the Baseline scenario. This case is characterised by the assumption that gas prices are no longer linked with the oil price.

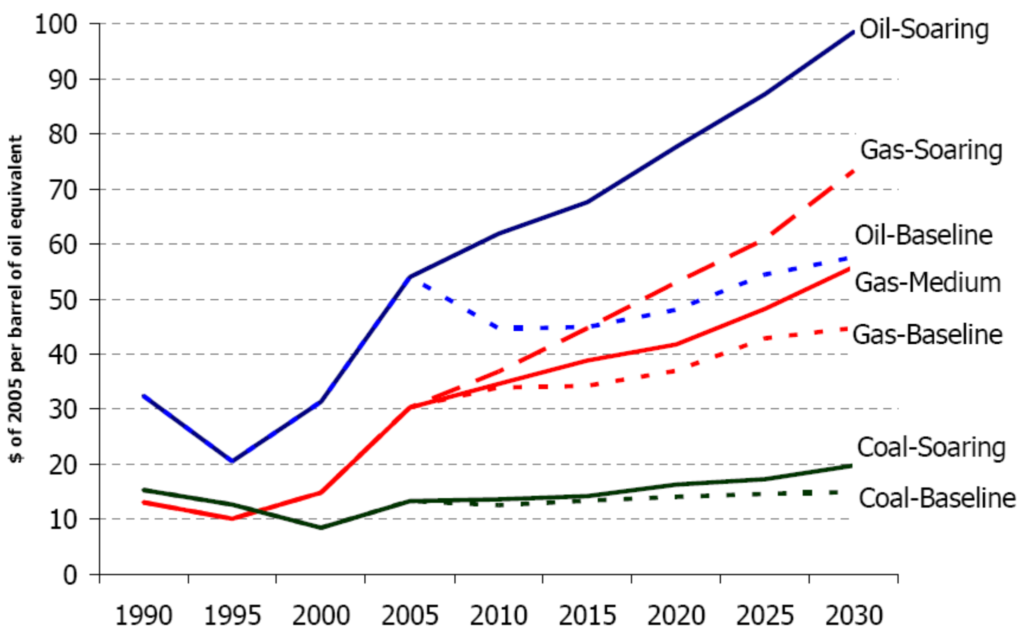
- "Soaring oil and gas prices" case in which the assumptions as regards economic growth and availability of fossil fuel resources are identical to those of the "Medium gas and soaring oil prices" case with gas prices remaining linked to the evolution of the oil price.

Figure 5.5 Oil price and Natural Gas Prices in €/GJ (deflated to 2005 price level) 1976-2005




Source: A. D. Hansen (2006), BP (2006), EUROSTAT (2006). Conversion to 2005 €/GJ

Figure 5.6 International energy prices for the European energy market under alternative world scenarios




Source: Scenarios on high oil and gas prices, 2006

In the “World medium gas and soaring oil prices” natural gas prices are assumed to exhibit a strong de-linking from the evolution of the oil price whereas in the “World soaring oil and gas prices” natural gas prices remain linked to the oil price. Thus, while oil and coal prices exhibit the same growth pattern in both cases, the growth on top of “World Baseline” levels for the natural gas prices in the “World medium gas and soaring oil prices” scenario is significantly less pronounced than in the “World soaring oil and gas prices” case (see Figure 5.3).

In the “World medium gas and soaring oil prices” case, the price of natural gas in the European market reaches 34.6 ($05) per boe in 2010 and 55.9$05 per boe in 2030 (2.1% and 24.8% higher than in the “World Baseline” scenario, respectively). In the “World soaring oil and gas prices” case, natural gas prices exhibit an even higher growth over the projection period reaching 36.8$05 per boe in 2010 (+8.8% from “World Baseline” levels, +6.5% from “World medium gas and soaring oil prices” case) and 73.3$05 per boe in 2030 (+64.0% from “World Baseline” levels, +31.3% from “World medium gas and soaring oil prices” case). The future energy fuel mix has been calculated in the report mentioned above by PRIMES model.

Table 5.5 Future energy fuel mix by the PRIMES model

| | **Mtoe** | | | | **% change from baseline** | | |
|---|---|---|---|---|---|---|---|
| | **2000** | **2010** | **2020** | **2030** | **2010** | **2020** | **2030** |
| Solid fuels | 306,5 | 288,7 | 267,5 | 285,8 | 0,7 | 3,1 | -2,5 |
| Liquid Fuels | 634,7 | 636,4 | 618,4 | 590 | -4,8 | -7,7 | -7,9 |
| Natural Gas | 376,3 | 473,6 | 533,2 | 510,1 | 2,5 | 0,7 | -1,5 |
| Nuclear | 237,7 | 248,8 | 229,7 | 223,3 | 0 | 0,5 | 5,9 |
| Renewable En. Sources | 96,5 | 146,6 | 207,1 | 252,5 | 2 | 6 | 9,4 |
| **Total** | **1653,8** | **1796,3** | **1858** | **1864** | **-0,9** | **-1,5** | **-1,7** |
| EU-15 | 1456,9 | 1573,2 | 1600,5 | 1581,3 | -0,9 | -1,4 | -1,7 |
| NMS | 196,9 | 223,1 | 257,5 | 282,6 | -1,1 | -1,5 | -1,4 |

Source: PRIMES

# 6 Transport technology and fuels

Most of the energy used for transport purposes today is in the form of oil products. 95% of the energy demand of total transport is fulfilled by petroleum products. The remaining 5% was provided by natural gas (for road transport and pipelines), electricity and coal (for rail transport) and biomass (in the form of liquid fuels) (IEA, 2006).

As oil products are the main energy source for transport and transport demand is rising, oil use in the transport sector nearly tripled in the non-OECD countries over the past thirty years. In 2003, transport generated nearly 60% of the final demand for oil world-wide and nearly two-thirds of the demand in OECD countries. In the past almost all global increases of oil products stemmed from the increase of transport demand and, furthermore, the energy demand for transport is expected to grow in the following decades (IEA, 2006).

Among transport sectors, road transport plays an important role and represents about three-quarters of global energy demand, while air transport consumes about 10% of global transport energy. In OECD countries, passenger cars and light trucks contribute to more than 50% and freight to about 30% of surface transport. Rail, bus, waterborne and other transport modes have a share less than 15% (IEA, 2006).

Analysing fuel consumption, it can be stated that petroleum based fuels such as gasoline, diesel and jet fuels dominate the market, a situation which has remained unchanged over the past years. However, three notable changes of the energy fuel mix can be observed: the shift to diesel vehicles in Europe, the electrification of railways in many OECD countries and the growth of bioethanol in Brazil (IEA, 2006).

The share of diesel cars and trucks in OECD countries rose from 1% in 1970 to 10% in the 1990s. Due to technological improvements (DLR, 2002) and tax incentives, diesel car sales were encouraged and their share reached a level of 32% in 2000 (IEA, 2006). Predictions of energy demand for the three main liquid fuels in the transport sector from 1990 to 2030 underline that an increase of the share of diesel consumption is expected (see Table 6.1).

Table 6.1 Finale energy demand for transport (Mtoe) by fuel type

| | 1990 | 2000 | 2010 | 2020 | 2030 |
|---|---|---|---|---|---|
| Gasoline | 132.1 | 129.8 | 142.1 | 145.4 | 141.6 |
| Kerosene | 29.2 | 45.1 | 53.0 | 63.3 | 72.0 |
| Diesel oil | 103.0 | 147.7 | 182.1 | 207.6 | 223.6 |
| Total | 264.3 | 322.6 | 377.2 | 416.3 | 437.2 |

Source: "EU 25 - Energy and transport outlook to 2030"

In the 1970s, more than two-thirds the energy demand for passenger rail was mainly supplied by diesel-fired locomotives in the OECD countries. By electrification of the railway tracks the use of electricity increased and in recent years the energy demand of diesel-fired locomotives is below one third.

***Proalcool programme in Brazil***

The fuel alcohol programme (Proalcool) in Brazil, launched in the 1970s, is the largest commercial application of biomass for energy production and use in the world. By December 1984, 17% of the country's car fleet was running on hydrated alcohol. The share of hydrous ethanol vehicles sold on the market rose to almost 100% in 1988, but it fell to less than 1% by the mid-1990s, as the sharp decrease in oil prices in the mid-1980s led to the revocation of the Proalcool plan in 1991. High oil prices in 2000 led alcohol cars to regain the favour of consumers, especially after the introduction of the flex-fuel technology. Such technology allows vehicles to run on any gasoline-ethanol blend and guarantees the flexibility that was not granted by dedicated alcohol vehicles. In 2002, the Brazilian Government began reviving the Proalcool programme: the industrial production tax was reduced for manufacturers of ethanol-powered cars and subsidies were introduced for the purchase of new ethanol cars. The Government also introduced credits for the sugar industry to cover storage costs in order to guarantee ethanol supplies. In November 2005, flex-fuel sales accounted for 71% of all cars sold in Brazil.

Source: IEA, 2006

## 6.1 Conventional oil refining

Oil refineries rely on well-established technologies, but they have to foster technological developments and to implement new technologies to satisfy stricter regulations. In the past, unleaded gasoline replaced leaded gasoline in the OECD countries. In the current situation, Europe and the US strongly endorse low-sulphur gasoline and diesel and it is expected that they will be the norm in 2010. Most other countries will reach this mix by 2030. (IEA, 2006).

Oil refineries face some technical difficulties to produce low-sulphur fuels, especially the ones using heavy and crude oil. In any case, the process of desulphurisation will require significant amounts of capital investment.

Besides policy regulations, the dynamics of the transport market also have an impact on the refinery sector. The growth of fuels for transport demand leads to a shift in the product mix of refineries. Lighter products, which are used in the transport sector, are more often produced. Furthermore, some technological developments in the transport sectors like auto-ignition in the combustion engine require the development of appropriate additives or other adaptations.

## 6.2 Non-conventional oil

There are three main types of non-conventional oil reserves, which are concentrated at specific places: tar sands from Canada, heavy oil from Venezuela and oil shale mainly from the United States.

Open-cast mining and in underground production are the most common production technologies to extract tar sands in Canada. In open-cast mining, the mined sand is transported to a processing plant where the bitumen is removed and cleaned. Afterwards, the bitumen is diluted and upgraded through refining. The costs of open-cast mining are lower than for underground production but the potential is only 10% of the whole tar sand potential in Canada (IEA, 2006).

The process of extracting tar sands is much more demanding. Current technologies use cyclical steam injection to reduce the viscosity of bitumen, which then allows the extraction. New technologies like the steam-assisted gravity drainage (SAGD) improve the recoverable fraction of hydrocarbons contained in the tar sands. This would increase the world reserves of tar sand and heavy oil strongly.

Similar extracting technologies could be also used to recover heavy oil in Venezuela. Here, the effort required to extract heavy oil is lower due to higher temperature of the reserves and therefore the lower viscosity of heavy oil. In this case only very limited thermal stimulation is needed for the recovery.

It has to be mentioned that the large deposits of heavy crude oil are well identified and therefore, there is no exploration risk (IEA, 2005). The current objective is to develop technologies, which lower the costs of production. It can be observed from the past, that appropriate tax framework enabled to develop the required technologies (IEA, 2005).

Currently, the extraction of oil shale is limited to some small-scale activities, mainly in Estonia, Brazil and China. If technology to economically recover oil from oil shale appeared, the potential of oil shale would be enormous, but it seems unlikely that shale oil recovery can be expanded in a way that they would have a major contribution. Still, the energy demands of blasting, transport, crushing, heating and adding hydrogen, together with the safe disposal of waste material, are large (WEC, 2004).

## 6.3 Methanol and dimethyl ether

Methanol is mainly produced from natural gas. It is used for production of chemicals, including methyl tertiary butyl ether (MTBE). Furthermore, methanol can be converted into dimethyl ether (DME).

Methanol, MTBE and DME can be used as fuel for combustion engines but, for varying reasons, the extensive use of these fuels is unlikely. Methanol is not miscible with hydrocarbons and therefore cannot be used for blending with gasoline. MTBE has been adopted as an additive to gasoline and, recently, demand has increased due to the higher demand for oxygenates and octane enhancers. These were necessary during the phase-out of lead gasoline and due to the higher demand of gasoline with a higher octane number.

The associated environmental impacts limit the use of MTBE. It is highly soluble and none-biodegradable in the groundwater. Even small concentrations of MTBE changes taste and odour of water und thus makes it undrinkable. DME has excellent combustion properties and, unlike methanol, is none toxic. The barriers to use DME are, to a greater extent, economic. To produce DME at costs, which enable competition with conventional fuels, large-scale plants have to be constructed. Furthermore, DME needs a different distribution infrastructure that has yet to be established. DME is gaseous at ambient conditions but can be liquefied under moderate pressure (JEC, 2006). This would require a distribution infrastructure comparable to that for liquefied-petroleum-gasification (LPG).

For this reasons it seems unlikely that DME is widely used in the short term. However, if the obstacles of the production costs and the distribution infrastructure can be overcome, DME might have a high potential. It is non-toxic and can be produced from multiple primary energy resources (IEA, 2006).

From a present point of view, the use of methanol and MTBE as fuel is not favourable as ethanol (and to minor extent Ethyl tertiary butyl ether (ETBE)) seems to be a better alternative. Ethanol can be used as blend and hasn't the negative impacts on water resources.

## 6.4 Biofuels

According to EC-DGTREN (2005), bio-fuels play an important role in the European energy policy, contributing to diversification of Energy sources in EU, reducing fossil fuel dependency and thus to the security of supply. Moreover, as bio-fuels are from renewable origins they contribute to meet EU climate change commitments.

Biofuels like ethanol, biodiesel and synthetic diesel fuel share three advantages (JEC, 2006):

- they don't require special infrastructure and can use therefore the existing infrastructure, if they are used as a blend[23];
- for blends there are negligible modifications necessary for the end user;
- biofuels can be mixed with conventional fuels in various proportions according to their availability.

It has to be kept in mind that these advantages occur using biofuels as a blend. If pure biofuels or blends with a high proportion of biofuels are used, negligible modifications of the vehicles or infrastructure are necessary. Biofuels are mainly produced from the conversion of oilseed crops - mainly sunflower and rapeseed - into fatty acid methyl esters or what is commonly known as biodiesel. The production of alcohol or bioethanol comes from the fermentation of sugar and starch based crops. Sugar beet, wheat and other cereals are the most commonly used in Europe.

Advanced bio-fuels are likely to play a role in the EU alternative fuels market from 2010 and they involve the production of bioethanol from lignocellulosic crops, which include modifications in the extraction of cellulose. Furthermore, new approaches include biomass gasification and thermo-chemical conversion and from the resulting biomass gas a wide range of synthetic bio-fuels can be produced. The latter have the advantage of using a wider range of

[23] This is not the case for DME which is discussed in the section before.

biomass feedstock and therefore its development would have an important impact in reducing further GHG emissions and increasing energy life cycle.

Biofuels have a significant potential to overcome traditional barriers of entry into the market due to their compatibility with vehicles without major engine modifications and they can also be blended with current fossil fuels such as gasoline and diesel. In fact, some low-percentage ethanol and biodiesel blends are already being distributed in service stations in Europe and worldwide without significant compatibility problems and avoiding new investments for infrastructure development. These features allow bio-fuels to be introduced rather rapidly in the existing passenger transport market.

As bio-fuels are obtained from renewable energy sources they also contribute to meet the 12 percent renewable energy target. Furthermore, they are considered to be roughly CO2 neutral as the amount of CO2 released by engines in the combustion process is captured during the organic material feedstock grow. According to various life cycle studies bio-fuels currently present in the EU market produce approximately two thirds less greenhouse gas emissions than fossil fuels, contributing to EU emission reduction targets under the Kyoto Protocol. In energy terms bioethanol provides approximately twice more energy as it is needed for production while biodiesel from rapeseed oil circa three times its energy input.

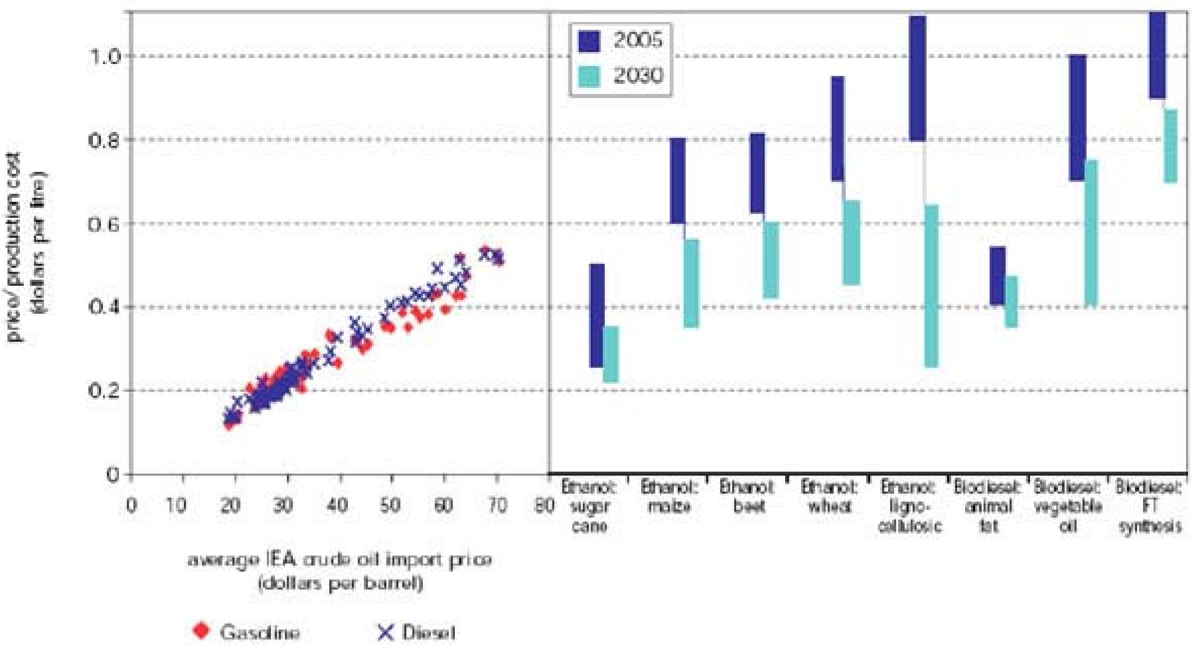
### 6.4.1 Policy implications

The implementation of bio-fuels in Europe already has an impact in other sectors of the economy such as agriculture and forestry markets. The demand for biomass products may have various effects such as an important increase for jobs and revenues to these sectors as well as changes in land use patterns and use of ring-fenced areas and less productive lands for energy crops production. It also has an important impact for newly accessed Member States as these countries have an important agricultural supply and the combination with bio-fuels and energy sector could increase their productivity options.

### 6.4.2 Costs and competitiveness

In most parts of the world outside Brazil, biofuels cost significantly more to produce than conventional gasoline or diesel, even with crude oil prices of over $70 per barrel (WEO 2006). This is a commercial barrier for its development, although costs have been declining over the last years as the technology has improved and economies of scale have been developed. Over time the cost of producing second-generation biofuels, including enzymatic hydrolysis and gasification of lingo-cellulosic biomass, might eventually fall as low as $40 to $50 per barrel, which would make them competitive with conventional gasoline and diesel at crude oil prices of 51-55$ (WEO 2006). The figure below shows the production cost of ethanol and biodiesel by different raw material, and the costs of gasoline and diesel by different oil import prices. The cost details regarding biofuels produced by ethanol and biodiesel will be described in the next paragraphs.

Figure 6.1 Biofuels production costs versus gasoline and diesel prices




Source: IEA analysis. Note: prices are monthly, from January 2000 to June 2006. Costs exclude subsidies to crops and biofuels production

### 6.4.3 Ethanol

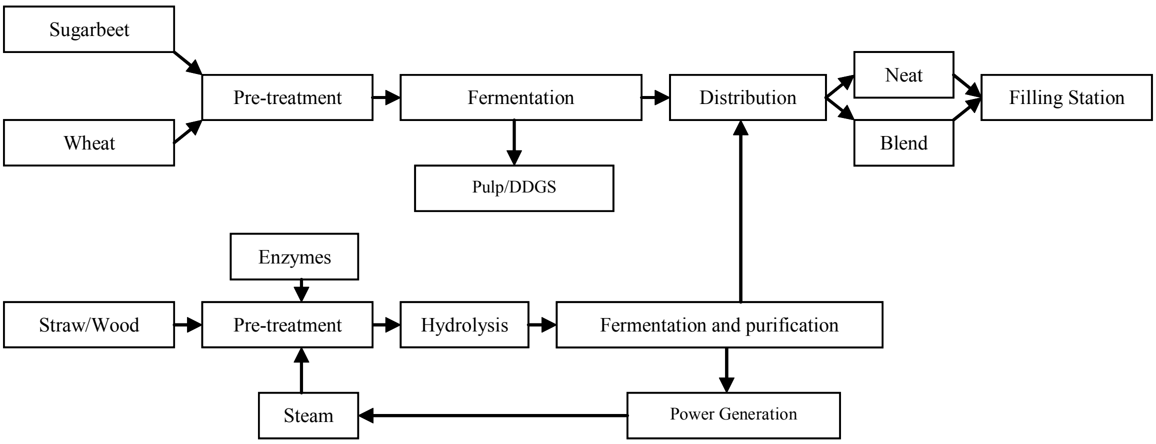
For bioethanol, the biomass options include sugarbeet, wheat (cereals), agricultural residues (e.g. straw), and dedicated and residual wood. The first two options are treated in the traditional fermentation process while lignocellulosic biomass is treated with enzymes and hydrolysis in order to extract lignin for ethanol production. The latter is a process in demonstration and research and development phase. Ethanol from sugarbeet and wheat produce DDGS and pulp for animal feed as well as electricity for the production process. The available information on possible bioethanol pathways is described in the following section where the database arrangements are specified and more detailed pathways including scale of production facilities and use of by-products are analysed from fermentation to the filling station as well as including the conversion step in existing and future vehicles types.

Bioethanol can be used in different ways to replace fossil based gasoline: as low blends (up to 10%) in the car fleet or high blends (85% and above) in dedicated flexi-fuel vehicles, or as ETBE to replace MTBE in the fuel production processes. ETBE is an additive to enhance the octane rating of petrol as a replacement of the fossil MTBE (replacing lead and benzene in unleaded petrol) and currently presents the most frequent use of ethanol in Europe with about 75% of total bioethanol (EC, 2007b). It is produced by etherification of ethanol and isobutylene or natural gas.

## Policy implications

The EU fuel quality directive (DIR, 1998) currently limits the blending of ethanol to 5% in volume terms, corresponding to a 3.4% share in volume terms. However, a recent proposal for its revision (EC, 2007a) would enable the use of higher ethanol blends of up to 10%, but recommends that such E-10 would be sold as a separate blend. In addition to the direct blending of ethanol into petrol, it can be used to produce ETBE (ethyl-tertiary-butyl-ether). Also for ETBE, the fuel quality directive sets a maximum limit for 15% in volume terms. As the ethanol content of ETBE is 47%, exhausting the maximum level implies that a bioethanol content of 4.7% can be achieved in the fuel through ETBE.

Figure 6.2 Production pathways for conventional and lignocellulosic bioethanol




Source: (TRIAS, 2006)

## Costs and competitiveness

Bioethanol production costs vary largely across countries, mainly due to climatic factors. Brazil has the lowest unit costs in the world, at around \$0.20 per litre (\$0.30 per litre of gasoline equivalent) for new plant (WEO 2006). In United States grain-based ethanol costs on average \$0.30/litre (\$ 0,45/litre per gasoline equivalent). In Europe, the ethanol production cost, including all subsidies, is about \$0.55/litre (\$0,80/litre of gasoline equivalent). Average production costs are projected to drop by around a third between 2005 and 2030. Costs in Europe and in the United States would be significantly higher without crop and ethanol subsidies.

Table 6.2 Unit costs and costs per litre of gasoline equivalent across some region

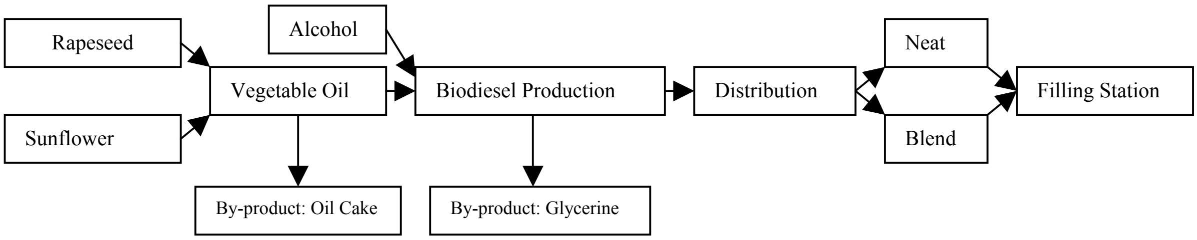
| | **Unit costs \$/Lt** | **Costs per litre of gasoline equivalent \$/Lt** |
|---|---|---|
| Brazil | \$0.20 | \$0.30 |
| Europe | \$0.55 | \$0,80 |
| United States | \$0.30 | \$0,45 |

Source: WEO 2005

### 6.4.4 Biodiesel and synthetic biofuels

Possible general biofuel pathways for biodiesel, bioethanol and synthetic fuels from renewable biomass feedstock are illustrated in the following pictures. For biodiesel, the biomass options are rapeseed and sunflower, which are crushed to produce vegetable oil and oil cake as a by-product for animal feed. Biodiesel production receives vegetable oil and alcohol (methanol or ethanol) transforming it into biodiesel and glycerine as a by-product. Biodiesel can either be distributed by road tanker or ship to refineries or depots to be blended with diesel fuel or sold neat at fuel stations. The available information on possible biodiesel pathways is illustrated in the following section where the database is described and more detailed pathways including scale of production facilities and use of by-products are analysed from vegetable oil production to the filling station as well as including the conversion step in existing and future vehicles types.

Figure 6.3 Possible general biodiesel pathways

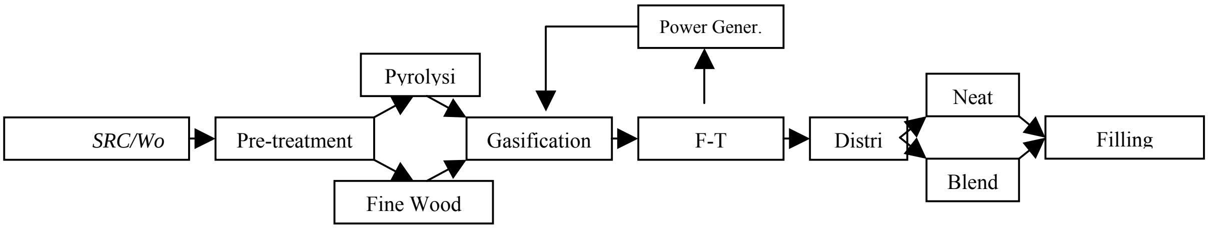



Source: TRIAS, 2006

Synthetic biofuels can be produced by different routes like natural gas (Gas-to-liquids GTL), coal (Coal-to-liquids CTL) and biomass (Biomass to Liquids BTL). We focus in the following section on BTL. For BTL the biomass options include short rotation crops (e.g. miscanthus, poplar, willow) as well as straw and residual wood. These options can either be pre-treated in various ways including fine wood particles chipping, torrefaction and flash pyrolysis. The pyrolysis and fine wood particles are considered as feasible pathways more possibly pyrolysis than fine wood chipping.

The corresponding option follows a gasification step with oxygen blown entrained gasifiers that results in hydrogen and carbon monoxide rich gas. In order to obtain liquids fuels, this gas after cleaning and conditioning is then conducted to the synthesis step (Fischer Tropsch Synthesis) where a variety of chemicals and fuels are obtained including F-T Diesel, Naphtha, Kerosene and others. A by product with the remaining off-gas is the subsequent generation of power used in the production process and also available for the electricity network through a combined cycle. The biomass to liquids routes is considered an extension application from the gas to liquids and coal to liquids technologies currently at commercial level.

Figure 6.4 Possible general synthetic fuels (BTL) pathways




Source: (TRIAS, 2006)

The importance of the BTL concept for future alternative fuels is the potential to use a wider range of biomass feedstock to produce them as well as the quality obtained for the research and development plants demonstrates high quality fuels with lower GHG emissions when compared to fossil diesel or gasoline options or even to existing conventional biofuels in spite of their high energy intensive processes. It should be noted that these saving potentials are obtained when using by-products for self-energy sufficiency of the processes.

The available information on possible BTL pathways is described in the following section where the database arrangements are specified and more detailed pathways including scale of production facilities and use of by-products are analysed from pre-treatment to the filling station including as well the conversion step in existing and future vehicles types (TRIAS, 2006).

**Costs and Competitiveness**

The IEA in its WEO 2006 estimates the current costs of conventional biodiesel production at just over \$0.60 per litre of diesel equivalent (based on rapeseed) and about \$0.50/litre in the United States (based on soybean). According to IEA technical breakthroughs on the standard transesterification process, leading to substantial cost reductions in the future, are unlikely. Production costs are projected to fall to just over \$0.30/litre in the United States and \$0.30/litre in Europe in 2030.

Table 6.3 Production costs ob biodiesel in EU and USA (actual and projections)

| | **Costs per litre of gasoline equivalent** | **Costs per litre of gasoline equivalent (projections by IEA to 2030)** |
|---|---|---|
| Europe | \$0.60/litre | \$0.30/litre |
| United States | \$0.50/litre | \$0.30/litre |

Source: IEA 2006

## 6.5 Hydrogen production

Hydrogen and fuel cell technologies for transport have been the subject of intensive research efforts during the last years. This trend is likely to continue due to the advantages of hydrogen as an alternative motor fuel. A vehicle running on hydrogen can help to reduce energy import dependency and greenhouse gas emissions, while at the same time improving local air quality and reduce noise pollution.

In fact, an effective solution for both the aspects of emission control and security of energy supply can be found in creating a large market for hydrogen, as it is an energy carrier that:

- it is emission-free at final use;
- can be obtained from a variety of different primary sources and
- can be utilised in different applications without the emission of any pollutant.

In particular hydrogen:

- can be produced from fossil fuels by conversion, with CO2 separation; this one can be considered the cleanest way to continue using these fuels, that in the future will also have an important role in our societies;
- can be produced from other sources (renewable, nuclear) without CO2 emissions;
- can be utilised in different applications (transportation, electricity production, etc.), not producing any pollutant except water steam.

Besides these advantages, it must be kept in mind that hydrogen is an energy carrier (like electricity), which implies that the way of producing it must be carefully addressed. The question is not so much about whether hydrogen could replace fossil fuels in the future but rather to develop H2 production routes that are environment friendly and economically viable.

Today, most hydrogen is produced from fossil fuels especially by means of steam reforming of natural gas[24] which is the cheapest option so far but not the cleanest. In the long term, fossil fuel based $H_2$ production will require $CO_2$ capture and sequestration (CCS) and a large proportion of hydrogen production might be produced by water electrolysis from non-carbon electricity sources i.e. nuclear and renewables. Alternative production routes like biomass gasification or direct production of hydrogen through biological processes might also become very important. Alongside low-carbon H2 production pathways, the main challenges focus on cost reduction of fuel cells in order to compete with other vehicles (e.g. hybrids, biofuels, LPG) and increasing technology maturity (e.g. H2 on-board storage).

Contrary to biofuels, H2/FC technologies are expected to enter the transport market in the long term (2030) but will still face major obstacles. A stable policy framework along with strong political will are essential to make the so-called "hydrogen economy" a reality.

[24] Steam Methane Reforming accounts for 48% of all hydrogen produced worldwide (95% in the U.S).

### 6.5.1 Policy implications

The European Union has thus been active in creating a vision for hydrogen. Building on the Green Paper on energy security [EC, 2000], the EU communication on alternative fuels for transport [EC, 2001] suggested of a 20% substitution by alternative fuels by 2020 through increased use of biofuels, natural gas and hydrogen. This communication identified hydrogen as an important alternative fuel for the long term that today still faces a lot of uncertainties regarding costs, benefits and market potential. As a result, a substantial market penetration of hydrogen would take place only after 2015. Market shares of 2% in 2015 and 5% in 2020 were considered by the Commission as an “optimistic development scenario” based on active policy.

In October 2002, the High Level Group on Hydrogen and Fuel Cells [HLG, 2003] presented R&D and non-technical actions required to move from today’s fossil-based economy towards a future sustainable hydrogen-oriented economy with fuel cells as converters. A European roadmap for hydrogen and fuel cells was established to guide this transition, setting targets for R&D, demonstration, investment and commercialisation. The targets foresee that by 2020 there will not yet be a significant contribution of H2/FC vehicles to the overall car fleet (2% only), but the share may reach 32% in 2040.

Moreover, as a main conclusion of their report, the High Level Group recommended the establishment of a Hydrogen and Fuel Cell Technology Platform (HFP)[25] in order to undertake concrete R&D support in this area. This platform constitutes the most important EU instrument tool to boost R&D development and deployment of H2-based technologies. The objective is to facilitate "the development and deployment of cost-competitive, world class European hydrogen and fuel cell based energy systems and component technologies for applications in transport, stationary and portable power”. It brings together people from industry, scientific and financial community, public authorities, users and civil society in order to develop a coherent European research and deployment strategy in the hydrogen and fuel cell sector, including public-private partnership, lighthouse projects, standards and regulations. It also aims to develop awareness of H2/FC market opportunities and foster European and international cooperation.

The HFP has elaborated (among others) the “Strategic Research Agenda” [HFP, 2005a], the “Deployment Strategy” [HFP, 2005b] and the “Implementation Plan” [HFP, 2007]. Regarding road transport, the goal is to "improve and validate hydrogen vehicle and infrastructure technologies to the level required for commercialisation decisions by 2015 and a mass market-rollout by 2020".

The implementation plan [HFP, 2007] sets the targets of 5,000 FCVs and 10,000 FC buses to be put on the market by 2015, paving the way for a wider deployment in 2020. Building on the work of the HFP (e.g. the implementation plan), H2/FC have been identified in the Commission’s proposal for FP7 as one of the six areas where a Joint Technology Initiative (JTI) could have particular relevance. This might represent a decisive step forward for the hydrogen-based technologies since the industry will have to take large-scale commercialisation decision.

[25] https://www.hfpeurope.org

### 6.5.2 Hydrogen costs and competitiveness goal

The US Department of Energy (DOE) has defined hydrogen competitiveness in a target of $2-3 per kg H2 at the pump (2005 prices) (US Department of Energy (DOE) (2005)).

The US DOE target is set from the expectation of a crude oil price of $34 corresponding to an estimated gasoline price of $1.26 per gallon before taxes. The fuel efficiency of a hydrogen and fuel cell vehicle (HFCV) is expected to exceed the fuel efficiency of a standard gasoline and internal combustion engine (ICE) system by 140% and that of a gasoline hybrid electric vehicle (HEV) by 66%. On a per kilometre basis this requires a hydrogen price of $3 and $2 per kg H2 respectively to be competitive with gasoline (US Department of Energy (DOE) (2005)).

Several reports have been addressed the cost of hydrogen and fuel cell solution in light duty vehicle (LDV) transport compared to conventional sources. They are all based on oil price expectations that nowadays must be regarded as unrealistic low (A.C. Hansen 2007). The National Academy of Science(2004) study was based on an oil of 30$ per barrel and the Joint Research Centre of the EU (2006) on oil price of 25$ and $50 per barrel.

The cost of this process depends strongly on economies of scale as well as economies of scope. The hydrogen produced today, take place in central air gas industry plant. The scale of production can be classified in three categories: Central, distributed, and household. If hydrogen is to be used in cars, the central production structure will hardly be competitive with distributed production based on the existing natural gas grid in the initial phases (A.C. Hansen 2007).

However, breakthroughs in targeted development of mini-systems could lead to a different path as innovative efforts are directed towards miniaturisation of natural gas steam reformers integrated in household size combined heat and power units. If sufficiently high conversion efficiency can be obtained at a reasonable cost, the hydrogen infrastructure becomes superfluous. The same could be the case with small electrolysers (A.C. Hansen 2007).

The costs of distributed natural gas based hydrogen production are only observable from experimental plants and plants supplying industrial customers. Assuming an oil price of $50 per barrel the Joint Research Centre of the EU Commission (2006) (WTW app. 2, p. 13) estimates the cost of hydrogen production on-site from natural gas at a 2MW plant as €7.1 per GJ for capital expenditure and €3.0 for operating expenditure. Of the latter, €0.43 per GJ is auxiliary energy and chemicals expenditure, the price of which depend on the oil price. This leaves a total of oil price independent costs for hydrogen production €10 per GJ.

Hansen 2006 analysed the competitiveness of natural gas based HFC transport depending on the oil price and the energy efficiency of HFC compared to traditional solutions. That part of the costs of transforming natural gas to hydrogen, which is independent from the wholesale natural gas price, is assumed to be €10-13 per GJ. A future cost level of $7 has also been included in the scenarios although being a very optimistic assumption.

The efficiency advantages scenarios are: 100% and 75% advantage efficiency of HFC compared to standard fuel and Internal Combustion Engine solutions (ICE), 50% advantage efficiency of HFC compared to grid independent Hybrid Electric Vehicle solutions. Another parameter considered is the conversion efficiency, which varies according to the hydrogen system production. The on-site production is assumed to provide a conversion efficiency value by 62%, and the central production a value of 70%.

The following table summarises the oil price required for hydrogen to be competitive under the four hydrogen supply assumptions and the three efficiency advantage assumptions.

The results indicate that HFC systems can become competitive against oil based LDV transport solutions that are only half as fuel efficient as the HFC system. Considering oil prices varying between \$65 and \$85 per barrel, even solutions with only 62% system efficiency can be competitive if the non-energy costs can be reduced to €10 per GJ. In other words HFC solutions will be competitive against conventional LDV solutions even at the current (2006) oil price if the vehicle costs are equal and the non-energy costs of hydrogen are €10 per GJ.

Table 6.4 Summary of oil price requirements for Hydrogen competitiveness under different assumptions

| | **Medium non energy costs** | **Medium non energy costs** | **High non energy costs** | **Low non energy costs** |
|---|---|---|---|---|
| | **Low efficiency** | **High efficiency** | **Low efficiency** | **High efficiency** |
| H2 Non Energy Costs | 10 | 10 | 13 | 7 |
| System efficiency | 62% | 70% | 62% | 70% |
| **Oil price: \$ per barrel, 2005** | | | | |
| 100% eff. advantage | 78 | 60 | 107 | 37 |
| 75% eff. advantage | 139 | 95 | 185 | 61 |
| 50% eff. advantage | 413 | 188 | 542 | 127 |

Source: Hansen, 2006

# 7 Studies on macroeconomic impact of high oil prices

## 7.1 Introduction

In general, economic analyses of the impact of high oil prices conclude that this should have a negative impact on the economy i.e. dampening growth. On the other hand the current high oil prices so far did not prove this common understanding, as the doubling of prices over a period of one year did not cause slowed growth. In particular sustained economic growth in the US, China and India is considered one of the main reasons behind recent increases in oil prices. Obviously there can also be identified winners of the high oil prices like the oil companies who increase significantly their revenues which could help them to invest in new energy technologies which in turn would increase investments. The same holds for oil exporting countries that can use their revenues for investments into other markets. Another category of winners could be countries that have invested in the usage of alternative energies in the past or in energy efficiency. These countries could gain a comparative advantage compared to less-energy efficient countries, because their cost base increases stronger. On the other side, European economies, in the presence of modest rate in economic growth, can be considered negatively affected by increases in oil prices driven by booming oil demand in other regions.

In this chapter some studies that specifically focused on the impact of high oil prices on the economy and employment will be mentioned. The aim is to provide some guidance on the potential impact of higher oil prices on variables such as employment and GDP. The interpretations of mechanisms in global markets for oil behind recent increases in oil prices will have to be taken into account to ensure relevance of HOP! scenarios and modelling.

Most macroeconomic modellers and research studies focused upon the changes in the nation’s output as measured by gross domestic product (GDP). Nevertheless, oil price increases provoke another important effect that attains the country’s income and the purchasing power. Even if the output is not directly affected by oil price increases, they will reduce the real domestic income. (H.G Huntington, EMF SR 9). The outcomes of the simulations are not strictly comparable, as they are based on different assumptions about prices, duration of the price increase and policy responses. Most such studies focus on the industrialised countries. The last paragraph of the chapter analyses the work made by STEPS project.

Contrary to the other models, which used a general macroeconomic approach, STEPS is based on two system dynamics models (ASTRA and POLES) The HOP! project will be also based on this type of approach.

## 7.2 Oil shocks in the past

It has been widely recognised that oil price is a factor that affects the economic performances and the world economy through several channels:

- the income is transferred from oil consuming countries to the producing countries[26];
- the increase in the costs of inputs to production can reduce the amount of non-oil output;
- impact on the financial market: reduction in revenues of the companies, restrictive monetary policy and subsequent increase in interest rates, inflation rise affects stock's value;
- impact on spending and country revenues: because of a low price elasticity of energy (gasoline, heating), the expenses of energy commodities increases and the demand of other goods and services decreases;
- the reduction of *business and consumer confidence* can lead to less investment.

The impact of higher energy prices on macroeconomic factors remain uncertain and therefore analysing the past oil shocks and the corresponding economic trends is important to understand the mechanisms of their linkage. US energy Information administration counts 24 episodes as oil disruptions occurred in the post-world Era. Hamilton (2005) identified 5 of them as having very negative impact on the economy, but many oil supply disruptions have had mild consequences for the economy (see Table 7.1).

## 7.3 Oil price development in the past

The behaviour of real oil prices since the late 1950s is graphed in Figure 7.1. The graph shows periods of price booms and price falls (the determination is based on a cycle-dating algorithm by Cashin and others (1999)). Contrary to the behaviour of oil price decline in the 1970s, since their sharp decline in the mid-1980s, the fluctuation of the real price was fairly stable with short time most deviations from the average price.

The key drivers of these oil price trends are not always well determined and they did not necessarily come from exogenous political events in the Middle East. For example, the increase in the real price of oil between March 1999 and November 2000 was a major one, but no military conflicts occurred during that period in the Middle East. A possible reason might be that the OPEC cartel might have triggered the rise of oil prices in 1999-2000. However, apart from the oil price shock in the 1999, it should be noticed that the OPEC countries were unable to force a sustained increase of oil prices since 1986[27]. In conclusion, the analyses of past real oil trends do not allow one to predict how future oil price cycles will evolve. The severity of price movements does not provide any information about their duration, and the time spent in a current boom or slumps provides no information about the likely future duration of that bump or slump (IMF 01).

[26] This reflects the assumptions that the oil exporting countries tend to spend less in the short run than the oil importing countries

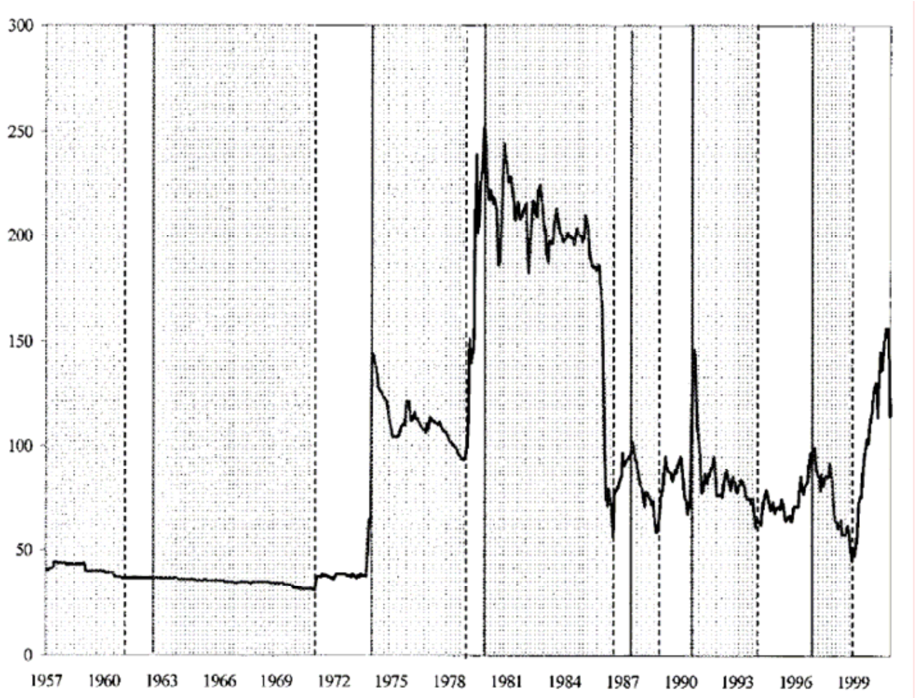
[27] For more information about oil past trend analysis see: Oil and the Macroeconomy Since the 1970's (Robert B. Barsky and Lutz Killian

## Table 7.1 Historic oil supply disruptions

| Oil Supply Disruption Event | | | Start Date | Disruption Length | Gross Shortfall | |
|---|---|---|---|---|---|---|
| Event # | Description | Cause of Disruption | mm/dd/yy | Months | In MMB D | As % of Demand |
| 1 | Iranian Fields Nationalized | Embargo/Economic Dispute | 03/01/51 | 44.7 | 0.7 | 7.1 |
| 2 | Suez War | Mideast War | 11/01/56 | 5.0 | 2.0 | 12.7 |
| 3 | Syrian Transit Fee Dispute | Embargo/Economic Dispute | 12/01/66 | 4.0 | 0.7 | 2.3 |
| 4 | Six Day War | Mideast War | 06/01/67 | 3.1 | 2.0 | 6.4 |
| 5 | Nigerian Civil War | Internal Struggle | 07/01/67 | 16.3 | 0.5 | 1.5 |
| 6 | Libyan Price Controversy | Embargo/Economic Dispute | 05/01/70 | 9.2 | 1.3 | 3.3 |
| 7 | Algerian-French Nat'l Struggle | Internal Struggle | 04/01/71 | 5.1 | 0.6 | 1.4 |
| 8 | Lebanese Political Conflict | Internal Struggle | 03/01/73 | 3.1 | 0.5 | 1.0 |
| 9 | October Arab-Israeli War | Mideast War & Embargo/Economic Dispute | 10/01/73 | 6.1 | 1.6 | 3.4 |
| 10 | Civil War in Lebanon | Internal Struggle | 04/01/76 | 2.0 | 0.3 | 0.6 |
| 11 | Damage at Saudi Oilfield | Accident | 05/01/77 | 1.0 | 0.7 | 1.4 |
| 12 | Iranian Revolution | Internal Struggle/Embargo | 11/01/78 | 6.0 | 3.7 | 7.0 |
| 13 | Outbreak of Iran-Iraq War | Mideast War | 10/01/80 | 4.1 | 3.0 | 6.0 |
| 14 | UK Piper Alpha Offsh. Plat. Explosion. | Accident | 07/01/88 | 17.3 | 0.3 | 0.6 |
| 15 | UK Fulmer Float. Stor. Vess. Acc. | Accident | 12/01/88 | 4.0 | 0.2 | 0.4 |
| 16 | Exxon Valdez Accident | Accident | 03/24/89 | 0.5 | 1.0 | 1.9 |
| 17 | UK Cormorant Offshore Platform | Accident | 04/01/89 | 3.0 | 0.5 | 1.0 |
| 18 | Iraq-Kuwait War | Mideast War & Embargo/Economic Dispute | 08/01/90 | 12.0 | 4.6 | 8.9 |
| 19 | Norwegian Oil Workers Strike | Internal Struggle | 05/01/96 | 1.0 | 1.0 | 1.4 |
| 20 | Local Protests in Nigeria | Internal Struggle | 03/01/97 | 1.0 | 0.2 | 0.3 |
| 21 | Local Protests in Nigeria | Internal Struggle | 03/01/98 | 3.0 | 0.3 | 0.4 |
| 22 | OPEC (ex. Iraq) cuts production in effort to increase prices. | Embargo/Economic Dispute | 04/01/99 | 12.0 | 3.3 | 4.4 |
| 23 | Venezuelan Oil Strike | Internal Struggle | 12/02/02 | 2.5 | 2.0 | 2.7 |
| 24 | Iraq War | Mideast War | 03/19/03 | 1.4 | 1.9 | 2.6 |

**Source**: Compiled from the U.S. EIA by Paul Leiby. See EIA website, "Global Oil Supply Disruptions Since 1951," http://www.eia.doe.gov/security/distable.html for one version of these data. Categorisations suggested by Paul Leiby. **Notes**: The EIA table concedes that "Definitions of >oil supply disruptions= are not entirely consistent from one case to the next." As an example of this variability, the latest version of the table (as of 1/02/2004), inexplicably, excludes the 1990 Iraq-Kuwait war and the Nigerian strikes in the late 1990s. There are some problems with these data, however. The ending dates of some disruptions are difficult to identify. Also, we are not sure whether disruption magnitude is consistently measured as initial (gross) loss or as a loss net of some market response from other suppliers.

Figure 7.1 Cycles in Real Oil Prices, 1957




Source: IMF 2001, Cashin, McDermott and Scott (1999). The deflator used to construct the series is a unit value index (in U.S. Dollars) of the manufacturing exports of 20 developed countries.

## 7.4 Different scenarios of oil prices increases

A sound calculation of the impact of oil price increases cannot set aside the different scenarios that might be produced and the different driven forces of the oil price increases. The Energy Modelling Forum report (EMF SR final Report) identified four different scenarios involving higher crude oil prices, emphasising the importance of considering the condition "higher oil price" and "oil price shock" as very distinct conditions.

The economic consequences of high oil price episodes depend also on the monetary policy response that prevail at the time of the price increasing, The EMF included the conditions in which the monetary policy can be effective in mitigating the economy recession: Low and high inflation and interest rate cases are depicted in the right-hand columns of Table 7.2. The estimates in the table are derived based upon EMF judgement about past research on the economic impacts of previous oil shocks. They represent the reduction in the real output (GDP) level (not the reduction in growth rates) and are presented as illustrative rather than definitive[28].

[28] "Estimates should be seen as conditional on the assumptions made by the investigator and on the tools used in the analysis. Barrels and Pomerantz (2004)

In order to determine the impact on the economy it is crucial to define what characterises an oil price shock and what the driving forces are that lead to one. EMF describes the relationship between supply disruption and prices, the distinction between sudden and gradual price increments and the two different types of driven forces leading to a shock (supply-driven and demand drive shocks[29]). Most large-scale macroeconomic models do not differentiate between the economic effects of oil price shocks and gradual oil price increases.

Table 7.2 Oil price and prior economic conditions

| | | **Low inflation and interest rates prior to oil price change** | **High inflation and interest rates prior to oil price change** |
|---|---|---|---|
| | | **Monetary Policy can be accommodating** | **Monetary Policy can not be accommodating** |
| Higher Oil Price | Oil prices move steadily higher but not rapidly over consecutive months | Policy Fix ( ~ 0%) | Slower Growth ( 2%) |
| Oil Price Shock | Oil prices move rapidly upward over consecutive months | Slower Growth ( < 2%) | Possible Recession (~ 5 %) |

Source: Energy Modelling forum - Huntington 2005

## 7.5 Macroeconomic consequences of higher oil price

Several studies distinguish between the "core" inflation effects and *OPEC tax* or CPI (consumer price index) effects. The latter occurs when the price increases affect wages and other prices, so that they influence the "core" inflation rate[30]. The former operate similar to an *OPEC tax* as the revenues are directed towards foreign oil producers. Oil importing countries suffer a reduction in their disposable income and as a result cut their spending on internal goods and services. Of course, the so-called OPEC tax effect on a country may be absent if foreign oil-producing countries spend their income at the same rate as the importing country does. Under the second condition, the Global Insight US model (Gault, 2005) reports the percentage losses in real GDP levels as a function of each $10 per barrel increase in crude oil prices[31]. This simulation is reasonably similar to other macroeconomic models used for forecasting and policy analysis.

[29] It is not clear that demand-driven shocks are any less painful than supply-driven shocks; what seems more important is whether the shocks are external or internal: when the USA is contributing to higher prices because it is growing faster, it is more likely that the US will be gaining rather than losing. (Hunlinghton 2005)

30 It occurs when a nominal oil price shock threatens the purchasing power by creating pressures for lower nominal prices for final products and non-energy inputs, the adjustment process is slowed with multiplying effects throughout the economy

[31] See EMF SR 2005

Table 7.3 Impacts of a permanent $10 rise in oil prices

| Year | 1 | 2 | …5 |
|---|---|---|---|
| Output | -0.3 | -0.6 | -0.4 |
| Price Deflator | 0.2 | 0.5 | |
| Unemployment | 0.1 | 0.2 | 0.2 |
| Interest Rates | 0.0 | 0.0 | |

Source: Global insight U.S. model simulation as reported by Gault (2005)
Note: Oil prices rise from $30 to $40(Percent deviation of levels from baseline)

A 2004 IEA study, carried out in collaboration with the OECD Economics Department and with the assistance of IMF, estimated the impact of a 10$ per barrel rise from $25 to $ 35 in the international oil price of importing regions and for the world as a whole (WEO 2006). As shown in Table 7.5 OECD Countries would lose up to 0,4% of GDP in the first and second years of higher prices compared to the base case. Inflation expressed as Consumer Price Index would rise by 0.5 percentage points and unemployment would rise by 0.1 percentage points.

A 2005 analysis by the International Monetary Fund quantifies the macroeconomic effects of an increase of about $37 in oil prices compared with the base case ($80 in 2005) on the global economy. International oil prices are assumed on average to fall back to the base case level by 2009. In that first year, GDP growth in the industrialised countries is projected to fall by 0.6 percentage points and by 0.8 points in developing Asia and other net oil-importing developing and emerging market economies (Table 7.4).

Table 7.4 IMF Analysis of the Macroeconomic Impact of an increase in the international Crude Oil Price to $80 per Barrel (percentage point deviation from baseline in the first year)

| | Base case | | Higher persistence case-real GDP growth |
|---|---|---|---|
| | Real GDP growth | CPI[32] inflation | |
| Industrialised countries | -0.6 | 1.0 | -1.0 |
| United States | -0.8 | 1.3 | - |
| Euro Area | -0.6 | 0.9 | - |
| Japan | -0.7 | 0.9 | - |
| United Kingdom | -0.4 | 0.9 | - |
| Developing and emerging market oil importers | -0.6 | 1.0 | -1.0 |
| Africa | -0.8 | 1.3 | - |
| Central and eastern Europe | -0.6 | 0.9 | - |
| Developing Asia | -0.8 | - | -1.3 |

Source: IMF (2005)

32 Consumer price index

Table 7.5 Macro-economic indicators in sustained Higher Oil Price case (%)

| | 2004 | 2005 |
|---|---|---|
| GDP | -0.4 | -0.4 |
| Consumer Price Index | 0.5 | 0.6 |
| Unemployment rate | 0.1 | 0.1 |
| Current account ($billion) | -32 | -42 |

Source: IEA/IMF
Note: Oil prices are assumed to be $ 10/barrel higher than in base case

The IEA in its World Energy Outlook 2006, using the outcome of Global Insight Scenario model and MULTIMOD from IMF estimated that a sustained $10 per barrel increase in international crude oil prices would cut average real GDP by around 0.3% in the OECD and by about 0.5% in non-OECD countries as a whole compared with the baseline. Overall world GDP would thus be reduced by about 0.4%. Oil-exporting countries would receive a boost to their GDP, offsetting part of the losses in importing countries. Oil-importing developing Asian countries would incur bigger GDP losses, averaging about 0.6%. Most of these effects would be felt within one to two years, with GDP returning broadly to its baseline growth rate thereafter[33].

## 7.6 The impact of high oil price in the STEPs research project

The main objectives of the STEPS[34] project were to develop, compare and assess possible scenarios for the transport system and energy supply of the future taking into account the state of the art of relevant research within and outside of the 6$^{th}$ Framework Research Programme. Using several modelling tools, the STEPs project explored a number of plausible scenarios considering both exogenous elements (e.g. economic growth, oil resources, technology developments) and policy measures. Some of these scenarios included the assumption of a 7% p.a. oil price growth until 2030.

In comparison to the studies quoted above, the STEPs application has the following remarkable features:

- the modelling system used for the simulation of scenarios was pivoted around two system dynamics models. A System Dynamics model consists of a set of hypotheses on the relationship between causes and resulting effects (see Forrester, 1987). Relationships are represented by equations that are written and solved by mathematical simulation. In other words, a System Dynamic model does not have a specific set of unknown parameters or variables whose value is estimated as a solution of the model. Instead, most of the model variables change over time as an effect of the existing reciprocal links and feed-backs (direct

---

33 WEO 2006

34 STEPS stands Transport System and Energy Supply and their potential effects; it has been funded by the European Commission within the Sixth Framework Programme. The project ran from January 2004 and finished in July 2006. *http:www.steps-eu.com*

and indirect). The model never reaches equilibrium, yet it evolves continuously, which is a more realistic description of the real world than “static” models do;

- the transport system is represented in some detail and not just as an aggregated sector among the others. As transport is one of the major consumers of energy, a more detailed representation of it is a key requirement to better understand the impact of higher energy price and to study the policy sensitiveness of the scenarios in order to enlarge the analysis to effects on the environment, the personal behaviour, etc.

In STEPs, The ASTRA system dynamics model, focused on describing the linkages between transport, the economy and the environment at the European scale, was used in conjunction with the POLES model (Christidis et al, 2003), which simulates the energy demand and supply for 32 countries and 18 world regions. Taking transport cost as a generalised cost, and transport demand as vehicles-kms, from the ASTRA model, POLES computed the fleet evolution and fuel price development. In turn, the fuel (resource) price forecast by POLES was used in ASTRA to revise the transport demand forecast, which is again fed into POLES.

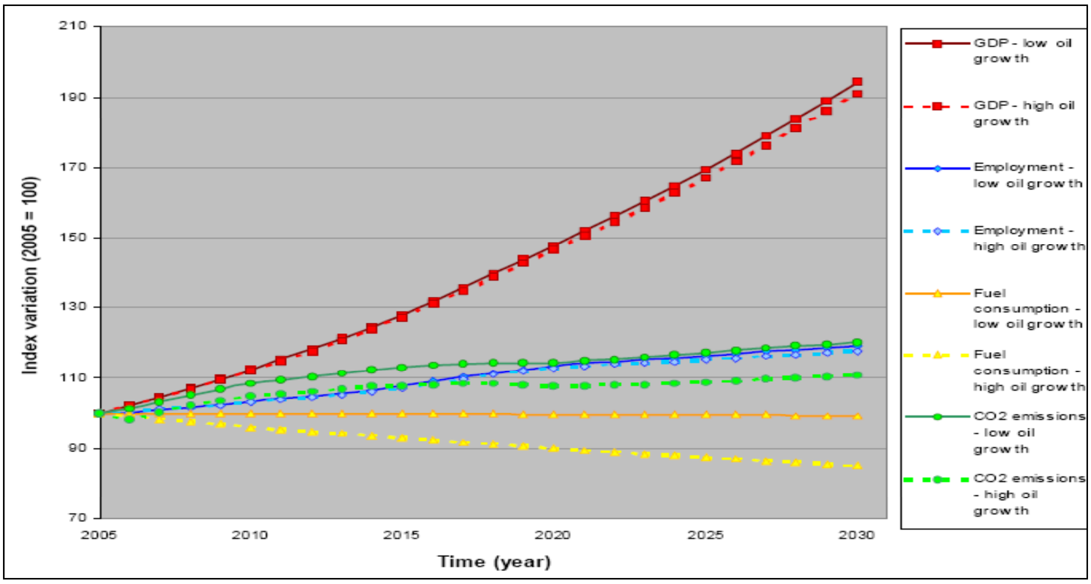
According to the STEPs results, the main consequence of a faster growth of oil price seems to be a pressure for improving efficiency and using alternative sources of energy. This impact has some important consequences.

- First, the demand/supply mechanism modelled led to a slower growth of fuels (gasoline and diesel) price than the oil price growth: on average about 4% p.a. compared to 7% p.a.. Fuel consumption decreases significantly as consequence of its higher price: at the year 2030, fuel consumption is reduced of about 25% with respect to the scenarios featuring low oil price growth. Some reduction of total mobility is observed and the growth of fuel price significantly affects car ownership, but total mobility is not dramatically reduced. Private road modes lose modal share slightly (passenger demand is more elastic than freight demand on this respect).

- Second, the effect on economy development as well as on transport demand is small. GDP and employment are grow sharply over the modelled period and their level at the horizon of 2030 is just a bit lower when compared to a slower pace of oil price development. Finally, polluting and greenhouse emissions are also downsized thanks to the development of new automotive technology. The following picture illustrates the changes of some key variables between high and low oil price growth scenarios for the EU 25.

The conclusion which can be drawn from the STEPs scenarios is that the effect of pure increases in oil price on the transport system and the economic growth can be small, provided that a reaction on the efficiency side takes place.

## Figure 7.2 The impact of high oil prices in STEPS




Source: STEPS

# 8 Transport and energy policies in the EU

The most relevant European policy documents as regards technology, transport and energy are shortly described in this chapter emphasising the aspects useful for the scenario design.

## 8.1 Keep Europe moving: sustainable mobility for our continent

The Transport White Paper (COM 2001 0370 (01)), published in 2001, proposed 60 measures to modernise the EU's transport policy, specifically; road congestion, freight and passenger transport, environmental concerns and security. Recent accomplishments include:

- Adoption of an air passengers rights charter;
- The introduction of the "Marco Polo" programmes;
- Revision of the Euro-vignette directive; creating a harmonised EU framework for charging heavy goods vehicles on intra-European motorways;
- Reinforcement of the position of railways, with the adoption of three packages of measures aimed at market liberalisation and harmonisation.

In 2006, the European Union released the mid-term review of the Transport White Paper, "Keep Europe Moving" (COM(2006) 314). This document intended to clarify the progress of European transport planning with respect to the White Paper, both at an intra-European and national level. The review also identified emerging areas of interest that were not considered in the original document, namely:

- **energy efficiency:** the new publication addresses the recommendations of the new Kyoto protocols and 2006 Green Paper, and cites the need for "RTD efforts and investments, including the combination of energy and transport research programmes, research in smarter and cleaner vehicles and use of Information and Communications Technologies for fuel efficiency." (p.15, COM(2006) 314);
- **co-modality and Intelligent Traffic Systems:** whereas the original White Paper proposed a modal transfer of private to public transport, the new publication has progressed to a recommendation of co-modality, also favoured by The International Road Transport Union and The association of European Rail Infrastructure. In other words, this proposes the utilisation of an array of transport services complemented by "new technologies coming to market (that) in the near future will gradually provide new services to citizens and allow improved real-time management of traffic movements and capacity use." (p.18 COM(2006) 314).

### 8.1.1 Significance of policy for HOP!

In order to reduce Europe's dependency on oil and make transport more sustainable, the commission will present a strategic technology plan for energy use in transport in 2007 and will launch a programme on 'green-powered vehicles' in 2009. This is also made apparent in recommendations for the introduction of bio-fuels, and second generation bio-fuels. This gradual introduction may alter or distort the current energy market, and consequently the relationship between market price and end user price may fluctuate unpredictably. This distortion should be acknowledged in any forecast.

Both the White Paper and mid-term review have recommended point-of-use charging for infrastructure as a means of revenue collection and traffic management tool. This could alter the proportions of private and public transport users, and hence affect oil demand.

Table 8.1 Time schedule of EC policy initiatives in the transport sector

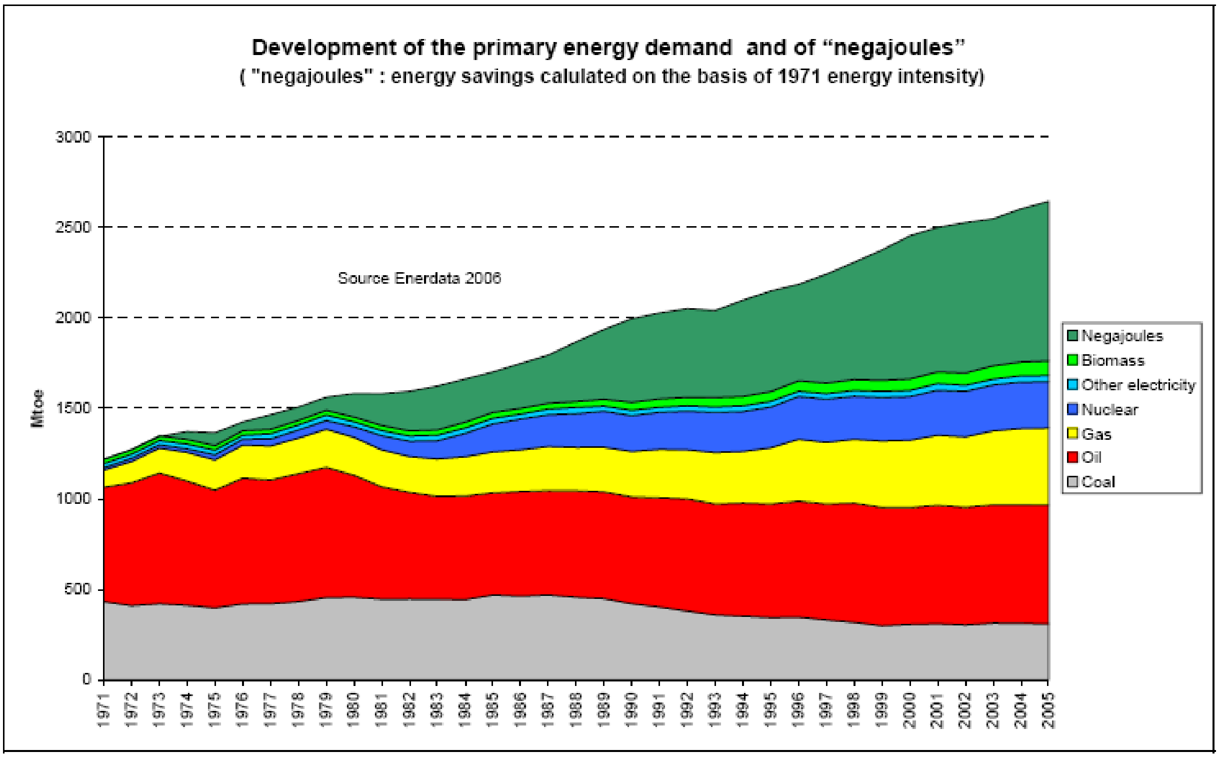
| Subsequent Dates | |
|---|---|
| 2007 | Publication of Green Paper on Urban Transport |
| 2007 | Development of a freight transport logistics strategy, as well as the launch of a broad debate on possible preparation of an EU action plan |
| 2008 | Smart charging (basis for methodology) |
| 2008 | Major programme to bring intelligent road transport systems to market |
| 2007/2009 respectively | strategic technology plan for energy and green propulsion programme |

Source: P.23, COM(2006) 314

## 8.2 EU Action Plan Energy package 2007

In January 2007, the Commission put forward a series of proposals for a unilateral 20% reduction in greenhouse-gas emissions by 2020 in a bid to reduce the EU's dependency on imported fuels and trigger a new 'industrial revolution' (SEC(2006) 317/2). The Commission initiated talks over a future common European Energy Policy and, as mentioned previously, published the Energy 'Green Paper' in March 2006. Suggestions include completing the opening of European gas and electricity markets and re-affirming ties with major energy providers such as Russia and OPEC. The communication also cites energy efficiency improvements will become a large resource, as the annual "negajoule" production, i.e. wasted energy, accounts for nearly 20% of total energy consumption. The increased energy efficiency can be seen in Figure 8.1.

Figure 8.1 Development of energy savings in the EU




Source: Enerdata 2006

In short, the Commission recommends:

- the continuation of dynamic energy performance requirements, such as the Eco-Design Directive and the Energy Star Regulation;
- completing the internal market for electricity and gas;
- a 20% target for renewables in the EU's overall energy mix by 2020 (current target is 10% for 2010);
- an obligation for each member state to have10% biofuels in their transport fuel mix by 2020, since approximately 26% of the energy demand in the transport industry is lost through inefficiencies;
- saving 20% of total primary energy consumption by 2020, an objective already expressed last year in an energy efficiency action plan. New initiatives here include proposals for an international agreement on energy-efficiency standards in appliance-producing countries;
- aiming towards "a low CO2 fossil fuel future" with support for clean coal technology, using carbon capture and storage deep underground. "Coal and gas account for over 50% of the

EU's electricity supply and will remain an important part of our energy mix", the Commission said;

- developing a common external energy policy to "actively pursue Europe's interests" on the international scene with major supplier, consumer and transit countries, including Russia;

- developing a European Strategic Energy Technology Plan to focus R&D efforts on low carbon technologies.

Due to sensitivity on the use of nuclear power, it was decided to leave the option to the decision of national governments. (Draft version, SEC(2006) 317/2)

***Market barriers to energy efficiency***

Regardless of the type of renewable source of energy, there are obstacles of a structural nature to its development. The economic and social system is based on centralised development around conventional sources of energy (coal, oil, natural gas and nuclear energy) and above all, around the generation of electricity. In many areas there already exist energy-efficient products and solutions that could lead to significant energy savings. In many cases these products and solutions seem to be financially very attractive for consumers, i.e. additional costs of the energy-efficient solution can quickly be recovered through the energy savings achieved. Despite this, enterprises and consumers often do not choose the energy-efficient solutions when buying new products. One of the objectives of energy-savings initiatives is therefore to improve the efficiency of the market so that financially attractive energy savings are implemented.

Obstacles to and market imperfections for energy efficiency in end-use sectors have been observed in OECD countries for more than 20 years. Obstacles vary by country for many reasons, including technical education and training, entrepreneurial and household traditions, the availability of capital, and existing legislation. Market imperfections include the external costs of energy use as well as subsidies, traditional legislation and rules, and traditions, motivations, and decision-making in households, companies, and administrations. Finally, an inherent obstacle is the fact that most energy efficiency investments remain invisible and do not contribute to politicians' public image. The invisibility of energy efficiency measures and the difficulty of demonstrating and quantifying their impacts are also important. The information available to the users of new technologies is scant. End users do not have sufficient technical knowledge to understand how this technology operates and the benefits provided. Even so, authorities concerned with energy saving in the transport sector have published documentation to provide the general public with information on the advantages for end users of these new technologies.

Source: STEPs (2005)

### 8.2.1 Significance of policy for HOP!

Again, the commission heavily emphasises the importance of strategic technological research in achieving efficiency gains. Bio-fuel technology is cited as a potential solution for transport energy saving, as well as fiscal measures to encourage public transport use and co-modality. New policies derived from this communication may alter any forecast of transport demand and coincidently energy demand.

The pressure for market liberalisation may also greatly affect energy prices for end users, as well as policy alterations due to Kyoto protocols, and hence alter energy and transport demand. However, European Policy Centre (EPC) Advisor Jørgen Henningsen argues that reliance on the Kyoto Protocol or energy market liberalisation will not encourage new technological innovation or efficiency savings, since the main barrier will be political rather than technological (Henningsen, 2006).

Henningsen concludes by saying that while technology can make a contribution to the climate change challenge, there is no doubt that there is already a vast range of existing technologies at our disposal which can make a real difference. However, he cites the greatest need as “political courage and a readiness to challenge strong vested interests”. This implies that technological advances may have little impact in terms of affecting transport modernisation and therefore transport demand.

Table 8.2 Time schedule of EC policy initiatives in the energy sector

| Subsequent Dates | |
|---|---|
| September 2007 | Commission to propose raft of follow-up measures, including strategic technology plan |
| Spring 2008 | Second Strategic European Energy Review |
| 2020 | Target date to achieve objectives |

Source: Communication from the Commission to the European Council: An Energy Policy for Europe, Draft Version

## 8.3 Strategic Energy Technology Plan

The Commission has outlined plans for a future EU energy research strategy as part of its energy and climate-change package of 10 January 2007. One of the aims of the strategy is to address the lack of intra-European coordination of energy efficiency research. The Commission declares that “All member states have their own research programmes on energy, mostly with similar objectives and targeting the same technologies, (additional public and private research) completes a picture of scattered, fragmented and sub-critical capacities” (COM(2006) 847 final).

The report recommends a range of options for improving the competitiveness of European energy innovation through a Strategic Energy Technology Plan (SET-Plan). These include bio-refineries, sustainable coal and gas technologies, fuel cells and hydrogen and generation IV nuclear fission. The outcome of this coordinated development would not only place Europe in the driving seat of renewables research, but also allow realistic policy changes in the following areas:

- the efficient conversion and use of energy in all sectors of the economy, coupled with decreasing energy intensity;
- the diversification of the energy mix in favour of renewables and low-carbon conversion technologies for electricity, heating and cooling;
- the decarbonisation of the transport system through switching to alternative fuels;

- full liberalisation and interconnection of energy systems, incorporating 'smart' information and communication technologies to provide a resilient and interactive (customers/operators) service network.

### 8.3.1 Significance of policy for HOP!

The proposals of the SET-Plan at the end of 2007 will give an indication of how research into renewable energies will be introduced over the next 20-30 years, and should give some indication of how innovation in transport fuel will develop.

Table 8.3 Time schedule of EC policy initiatives in the energy technology sector

| Subsequent Dates | |
|---|---|
| May 2007 | Commission to consult established advisory groups (high-level group on competitiveness, energy and the environment. |
| July 2007 | Commission to launch public consultation on a preliminary draft Strategic Energy Technology Plan (SET-Plan). |
| Dec 2007 | First SET-Plan to be adopted. |
| March 2008 | Spring Summit to endorse SET-Plan. |

Source: “Brussels urges 'sea-change' in EU energy research”, Euractiv.com
http://www.euractiv.com/en/energy/brussels-urges-sea-change-eu-energy-research/article-162272?Ref=RSS

## 8.4 Stimulating technologies for Sustainable Development

In January 2004 the Commission launched an action plan to stimulate the development and use of environmental technologies. The action plan aims at removing financial, economic and institutional barriers to the development of environmentally friendly technologies. The Commission sees it as a bridge between the EU's sustainable development strategy and the Lisbon agenda. The proposed actions have three main objectives:

- to help make the transition from research to markets (by increasing and focusing research, establishing technology platforms and networks for technology testing);
- to improve market conditions (by setting performance targets, leveraging investment, creating incentives and removing economic barriers, promoting environmental technologies via public procurement, building support for environmental technologies in civil society);
- to act globally (by promoting environmental technologies in developing countries, and promoting responsible foreign direct investment).

## 8.5 Development of the carbon emission trading

In January 2005, the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) commenced operation as the largest multi-country, multi-sector Greenhouse Gas emission trading scheme world-wide. The scheme is based on Directive 2003/87/EC, which entered into force on 25 October 2003. It aims at reducing emissions of carbon dioxide and combating the serious threat of climate change. Under the scheme, each participating country has a National Allocation Plan (NAP) specifying caps on greenhouse gas emissions for individual power plants and other large point sources. Each facility gets a maximum amount of emission "allowances" for a particular period. To comply, facilities can either reduce their emissions or purchase allowances from facilities with an excess of allowances. Progressively tightening caps is foreseen for each new period, forcing overall reductions in emissions.

The European Environment Agency recently published the second report on how Member States have implemented the Emissions Trading Scheme, including the monitoring, reporting and verification process. Reflecting on the first full year of the Scheme's operation (2005), the report provides a compilation of experiences from 23 Member States. The report is based on information that Member States have to provide in accordance with Article 21 of the Emissions Trading, by means of a questionnaire[35].

[35] See http://reports.eea.europa.eu/technical_report_2007_4/en

# 9 Conclusions: inputs to HOP! scenarios design

- The global primary energy demand is projected to increase. According to the study analysed, the world energy consumption growth averages from 1.7% to 2% to 2030, with fossil fuels being dominant to 2030.

- The long term oil demand projections for most agencies are based on demand drive factors such as real GDP growth and population. In the reference scenario of the studies considered the global oil consumption reaches 99 MB per day in 2015 and 116-118 Mb /d in 2030.

- Transport demand, which uses up 95% of petroleum products, is projected also to increase (in the European Union it will approximately grow by 10% between 2005 and 2030).

- To what extent the oil supply will meet the demand at reasonable oil prices is quite controversial. There is general uncertainty in defining the oil and gas reserves and resources. The oil proven reserves estimates can range from 800 to 1580 Bbl. The amount of oil and gas discoveries that will be added to the reserve base as commercially exploitable in the next 30 years is also uncertain.

- It is generally acknowledged that OPEC members, who own 70% of world oil reserves and have relatively low production costs, can accommodate sizeable increases in oil demand. However, the actual OPEC response to demand pressures is difficult to predict. Geopolitical tensions in Middle Eastern regions may occur, provoking oil supply disruption despite the actual oil availability.

- An increasing scientific movement predicts in the near future a peak in the oil production. Some models already consider that the world oil production peaked in 2006, others state that it will not peak before 2030. In this case, the role that non-traditional or unconventional liquid fuel can play in the future energy scenario should be relevant.

- The role that a high oil price can play in increasing the investments in more oil capacity is not clear. There is more consensus on the effect of higher oil price on demand side (price response in gasoline prices can be about –0.08% to-0.12 % as confirmed by econometric studies). The response of oil production to price changes is more uncertain. In the past experience the production effects to oil price changes have been not remarkable.

- The oil prices projections assumed in the studies range from $52 per barrel in 2030 in reference scenarios to $99/Bl in 2030 when soaring oil prices scenario is assumed (in real year-2005) However, in the studies it is envisaged the possibility of much stronger oil prices increases driven by supply disruption or geopolitical tensions.

- The price has been modelled in most studies primarily as a consequence of oil supply and demand. Nevertheless, it is generally thought that another factor such as limited production capacity can dictate prices. The current high oil price is a consequence of systematic under-investment, which has eroded the spare capacity on the supply side.

- Most of the studies considered derived the Natural Gas demand from a gas price assumed that is linked to the oil import price. If the gas price is decoupled from oil prices, relevant changes in the fuel mix as well as in terms of improving energy intensity can be expected.

- The increase in oil and gas prices would encourage the development of new technology based on renewable sources. Transport sector uses of hydrogen and biofuels might play an important role in the near future. In Europe conventional biodiesel production is estimated at just over $0.60 per litre of diesel equivalent, which means that only oil crude prices of over $70 would make this option competitive against conventional gasoline and diesel. The availability of space for producing large amount of biofuels and the environmental impact of life-cycle production should be taken into account.

- Contrary to biofuels, Hydrogen/Fuel Cells technologies are expected to enter the transport market in the long term (2030) but will still face major obstacles. However, HFC solutions will be competitive to conventional LDV solutions even at the current (2006) oil price if the vehicle costs are equal and the non-energy costs of hydrogen are €10 per GJ

- The impact of higher energy prices on macroeconomic factors remains uncertain. The analyses of past real oil trends do not allow a prediction of how future oil price cycles will evolve. A sound calculation of the impact of oil price increases should differentiate between the economic effects of oil price shocks and gradual oil price increases. The effects of high oil prices on the economy of certain countries are also expected to be different according to different type of shock occurred (e.g. Internal or External Demand shock)

- From the macroeconometric studies analysed, a provisional observation can be derived; a sustained $10 per barrel increase in international crude oil prices would cut average real GDP by -0.3% -0.5% as a whole compared with the baseline, with different impact on OECD and Non-OECD countries or whether oil-exporting or oil importing countries are considered. Most of these effects would be felt within one to two years, with GDP returning broadly to its baseline growth rate thereafter.

- According to the system dynamic model STEP the effect on economy development as well as on transport demand is small. GDP and employment grow sharply over the modelled period and their level at the 2030 horizon is slightly lower when compared to a slower pace of oil price development.

- In STEP the demand/supply mechanism modelled led to a slower growth of fuels (gasoline and diesel) price than the oil price growth: on average about 4% p.a. compared to 7% p.a.. Fuel consumption decreases significantly as consequence of its higher price

# 10 References

(UNPD, 2005), United Nation report, World Population Prospects: the 2004 Revision

ACROPOLIS- IER-JRG Assessing Climate Response Options: policy Simulations

Aguiar-Conraria, L.F. and Wen, Y. (2005). *Understanding the Impact of Oil Shocks*. Portugal, NIPE, Universidade do Minho. Working Paper.

Bacon, R. and Kojima, M. (2006). *Coping with Higher Oil Prices 2006*. Washington, The World Bank.

Bakhtiari, A.M.S. (2004). World oil production capacity model suggests output peak by 2006–07. *Oil and Gas Journal*, 18–20.

Barrell, R. and Pomerantz, O. (2004). Oil Prices and the World Economy. London, National Institute Economic and Social Research Discussion Paper 242.

Barsky, R.B. and Kilian, L. (2004). *Oil and the Macroeconomy Since the 1970s*, National Bureau of Economic Research,

Campbell C.J. (2005). *Oil Crisis*. Essex, Multi-Science Publishing Co., U.K.

Campbell C.J. and Laherrµere J.H. (1998). The End of Cheap Oil, *Scientific American*, March, 78{83.

CERA, (14 November 2006). World Running Out of Oil Soon – Is Faulty; Could distort policy & Energy debate. Cambridge, Massachusetts. *CERA*. Accessed 07 June 2007

COM 2001 0370 (01)

COM(2006) 314 Draft version, SEC(2006)

EC - European Energy and Transports Scenarios on Key Drivers 2004 (DG TREN)

EC – Institute of Communication and Computer Systems of National Technical University of Athens (ICCS-NTUA) European Energy and Transport – Scenarios on high oil and gas prices

EC – National Technical University of Athens - European energy and transport trends to 2030

EC – National Technical University of Athens - European energy and transport trends – update 2005

EIA-DOE International Energy Outlook 2006

EUCAR- JRC/IES - Well-To-Wheels Analysis 2006

Euractiv.com, (07 March 2007). Brussels Urges "Sea Change" in EU Energy Research. *www.Euractiv.com*. Accessed 07 June 2007

Guseo, R., Dalla Valle , A. (2006) *World Oil Depletion Models: Price Effects Compared with Strategic or Technological Interventions*, University of Padua, Italy. Department of Statistical Sciences.

Henningsen, J. (2006). Rising to the energy challenge: key elements for an effective EU strategy. Brussels, *EPC*, Issue Paper No.51, Dec 2006,

IEA – Energy Technology Perspectives 2006

IEA – World Energy Outlook 2006

IEA – Resources to Reserves 2005

IMF – World Economic Outlook 2007

IMF- 4th chapter of World Economic Outlook (Will the oil market continue to be tight?)

Insights from using national and international models

Journal of Economic Perspectives, Fall 2004, 18 (4): 115-134.

Klepper G. and Peterson, S. ID 42980

Lynch M.C. (2002). Forecasting oil supply: theory and practice, *The Quarterly Review of Economics and Finance 42*, 373{389.

Lynch M.C., (2003) The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers), *Minerals and energy 18*, 21{32.

OPEC annual Report 2005

Simmons W. (2000). Is Oil Price Shock Around The Corner? *The American Oil & Gas Reporter*, Kentucky

STEPS – Scenarios for the transport system and Energy supply and their Potential effects

STEPs (2005): D2.1 Overview of relevant trends and translation into parameters

Transust project – the role of energy prices for assessing the costs of climate change policies.

TRIAS – Sustainability Impact Assessment of Strategic Integrating Transport, Technology and Energy Scenarios

Tyndall Centre – World Transport scenario project 2005

WETO-H2 – World Energy technology outlook 2050

# 11 Glossary

**Conventional oil** is defined as crude oil and natural gas liquids produced from underground reservoirs by means of conventional wells. This category includes oil produced from deep-water fields and natural bitumen. Conventional oil includes liquid hydrocarbons of light and medium gravity and viscosity, occurring in porous and permeable reservoirs. If such hydrocarbons require enhanced recovery techniques, Laherrere (2001) and Rogner (1997) consider them to be unconventional oil.

**Crude oil**: a mixture of hydrocarbons that exists in a liquid phase in natural underground reservoirs and remains liquid at atmospheric pressure after passing through surface separating facilities. Production volumes reported as crude oil include:

- liquids technically defined as crude oil;
- small amounts of hydrocarbons that exist in the gaseous phase in natural underground reservoirs, but which are liquid at atmospheric pressure after being recovered from oil well (casing head) gas in lease separators;
- small amounts of non-hydrocarbons produced with the oil.

**Derived energy sources** are produced from the primary energy sources by converting them into other forms of energy for end use consumption. Examples are electricity, petroleum products and heat.

**Energy conservation** is usually taken to refer just to the energy saving on the demand side.

**Energy efficiency** is a measure of the overall efficiency of providing energy services, ie, the efficiency with which energy is produced from primary resources, transformed into useful forms, delivered to end users and consumers.

**Energy intensity** is a statistical measure which relates energy consumption (eg, gross inland consumption) to the level of economic activity (e.g. GDP). Thus trends in energy intensity reflect changes in the amount of energy needed to produce a unit of economic output. This indicator is dependent on the efficiency of using energy for the various energy services required (eg, light, heat, power) and the structure of economic and social activities (eg, a high proportion of heavy industries consuming large amounts of fuel being used at comparably low efficiency, versus a service-oriented society).

**Estimated Ultimately Recoverable (EUR) oil**. This is oil that is infeasible to recover for reasons that are either economic or technical. This category also includes yet-to-be-found oil.

**Final energy consumption** is the consumption of primary and derived energy by the end-use sectors: mainly industry, transport, and households and services/commerce. Final energy consumption is always lower than gross inland consumption since it does not include the energy losses in conversion and distribution..

**Gross energy consumption** corresponds to the total primary energy consumed, including quantities delivered to marine bunkers.

**Gross inland consumption** (or Total Primary Energy Supply (TPES)) is indigenous primary production, plus imports, minus exports and international marine bunkers, and plus/minus stock changes of primary energy.

**Gross production**: the total flow of natural gas from oil and gas reservoirs of associated-dissolved and non-associated gas.

**Marketed production**: corresponds to gross production, minus the volumes of gas flared or re-injected into fields, minus the shrinkage.

**Natural gas:** a mixture of hydrocarbon compounds and small quantities of various non-hydrocarbons existing in the gaseous phase or in solution with oil in natural underground reservoirs at reservoir conditions.

**Natural gas liquids (NGLs):** those reservoir gases liquefied at the surface in lease separators, field facilities or gas processing plants. NGLs consist of field condensates and natural gas plant products such as ethane, pentane, propane, butane and natural gasoline.

**Non-Conventional oil (BP):** Oil from coal, oil shale, oil sands, tar sands, bitumen, heavy and extra heavy oil, deep water oil, polar oil and natural gas condensates.

**Non-conventional oil:** includes oil shales, oil sands-based extra-heavy oil and derivatives such as synthetic crude products, and liquids derived from coal (CTL) and natural gas (GTL).

**Primary energy sources** include non-renewable fossil fuels (mainly solid fuels, crude oil, natural gas), nuclear power and renewables such as hydropower, geothermal, biomass and solar energy. Combined together, they provide a measure of primary energy production. Primary sources may be divided into two further categories in respect of their impact on global warming: carbon-intensive (solid fuels, oil, gas) and low- or zero-carbon (wind, solar, biomass, hydropower, geothermal and nuclear).

**Proven Reserves** (BP) defines “the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions”.

# 12 List of abbreviations

CA = Carbon Abatement

CDM = Clean Development Mechanisms

CER = Certified Emission Reduction

CHP = Combined heat and power

CIS = Community of Independent States (1)

EIA = Energy Information Administration of the United States Department of Energy

EEA = European Environment Agency

EMF = Energy Modelling Forum

EU = European Union

EU15 = EU member states (15 countries) before May 2004

GDP = Gross Domestic Product

GHG = Greenhouse Gas emission

GTCC = Gas Turbine Combined Cycle

Gtoe = Billion of tons oil equivalent

GWP = Global Warming Potential

HFC= Hydrogen/Fuel Cells

IEA = International Energy Agency

IEPE = Institute of Energy Policy and Economics

IET = International Emission Trading

ICE = Internal Combustion Engine

IGCC = Integrated coal gasification combined cycle

IIASA = International Institute for Applied System Analysis

IMF = International Monetary Fund

IPCC = Intergovernmental Panel on Climate Change

LNG = Liquefied Natural Gas

LWR = Light water reactor

MMBD = Million Barrel per day

Mtoe = Million ton oil equivalent

NEMS = National Energy Modelling Systems

OECD = Organisation for Economic Cooperation and Development

OPEC = Organisation of Petroleum Exporting Countries

PEM = Proton Exchange Membrane

POLES = Prospective On Long Term Energy Systems

PPP = Purchasing Power Parities

R&D = Research and Development

RSMT = Region Sector Medium Term Scenarios

SFC = Solid oxide Fuel Cell

SRES = Special Report on Emission Scenarios by IPCC

TOE = Ton of oil equivalent

TR-EN = Transport and Energy Scenarios

TWh = Billion kWh

UAE = United Arab Emirates

UN = United Nations

UNFCCC = United Nations Framework Convention on Climate Change

URR = Ultimate Recoverable Resources

US-DOE = US Department of Energy

VLT = Very Long Term Scenarios

WBCSD = World Business Council for Sustainable Development

WEC = World Energy Council

WETO = World Energy, Technology and Climate Policy Outlook